# CHAMELEONS FOR CONSERVATION:
# SURVEYING AND MONITORING IN CENTRAL MENABE MADAGASCAR

Final Report

**Future Conservationist Award 2006**

By

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## Summary

Only four Malagasy chameleon species are currently considered threatened by IUCN Red Data Book. One of these, *Furicfer labordi*, is restricted to the western dry deciduous forest and is thought to be threatened from habitat destruction. Part of its range encompasses the forests of central Menabe, a large block of relatively intact deciduous forest that was designated as a new protected area in 2006. A survey of the chameleons was undertaken in nine forest sites, representing different degrees of human disturbance, from January to April 2007. The structure, distribution and abundance of chameleon populations were described using distance sampling along nocturnal transects «path and forest» (n = 107 or 20.8 km). The habitat preference for each species was analyzed by installing quadrats of 5 x 5 m in areas with or without roosting chameleons. Availability of potential prey within each habitat type was studied by sampling invertebrates using a sweep net. The faecal pellets of animals captured were collected and analyzed to determine the diet. To establish the structure of each population, chameleons were measured the day after capture. A total of 671 individuals from four species were recorded. The dwarf chameleon *Brookesia brygooi* was the most abundant (492), followed by *Furcifer labordi* (90), *Furcifer nicosiai* (70) and *Furcifer oustaleti* was the rarest (19). Highest species richness was found in Tsitakabasia, Kiboy, Kirindy CFPF and Ampataka forests. The density of *B. brygooi* varied from 3.7 individuals per hectare in Bedo baobab Forest to 92.1 individuals per hectare in Tsitakabasia and Kiboy forests. *Furcifer labordi* density was highest in Bedo baobab forest (20 individuals per hectare) and lowest in Ankoraobato-Marofandilia (0.7 individual per hectare). Chameleon species appear sensitive to habitat disturbance. The density of *F. nicosiai* was always lower than that of *F. labordi* regardless of the habitat disturbance levels. The highest abundance of *F. labordi* and other amphibian and reptilians species inside the Bedo baobab and Kirindy CFPF forests makes these areas important for herpetofaunal conservation in central Menabe. Chameleons are a viable indicator species in central Menabe but the likely long-term availability of the necessary technical and logistical requirements need to be considered before integration into the area's monitoring protocol.

# INTRODUCTION

Madagascar is one of eight “hottest” biodiversity hotspots. The eastern littoral and the western dry deciduous forests are classified as top priorities for conservation (Ganzhorn *et al*., 1997, 2001). The Menabe region encloses one of the largest remaining dry forests in western Madagascar (Nelson and Horning, 1993) and its central parts has been declared a new protected area in 2006 as part of Durban Vision. Its survival is a necessity to prevent animals such as the Malagasy giant jumping rat *Hypogeomys antimena* and the flat-tailed tortoise *Pyxis planicauda* from going extinct. The NGO Durrell Wildlife Conservation Trust (DWCT) coordinates the biodiversity assessment in Menabe and is responsible for developing the long-term monitoring at the site. Our project is planned to respond the invitation from the Malagasy government to provide technical assistance in first mapping and the monitoring the forest’s biodiversity.

In general, species diversity in amphibians and reptiles is lower in the west than in the rain forests of the east (Glaw and Vences, 1994). However, the herpetological fauna of the west is very different to that of the east (Glos and Volahy, 2004). Raxworthy and Nussbaum (2006) reported that Madagascar is the global centre of chameleon diversity and new species continue to be found. Over 66 species, including 26 dwarf chameleons (*Brookesia*), 22 *Calumma* and 18 *Furcifer* are known from Madagascar (Raselimanana and Rakotomalala, 2003) and six news species of *Calumma* were recently described by Raxworthy and Nussbaum (2006). Chameleons are of a particular conservation interest by virtue of their high degree of endemism, interest to tourists and popularity in pet markets (Brady and Griffiths, 1999). Some species have small geographic distributions and these regional endemics are frequently the most vulnerable to extinction.

Glos and Volahy (2004) reported that chameleons composed 39% of all reptiles found during their survey of central Menabe. Of the four chameleon species known from Menabe, *F. labordi* is listed as vulnerable by IUCN and is restricted to the south-west of Madagascar. Other *Furcifer* known from central Menabe include the recently described *F. nicosiai* (Jesu *et al.* 1999), and the widespread *F. oustaleti*, and *F. lateralis. Furcifer* chameleons can grow very large (up to 685 mm TL). In the east, these species are usually found in degraded open habitats but in the west some species, like *F. labordi* and *F. nicosiai*, are thought to require relatively undisturbed forest.

Despite high chameleon diversity, their cultural importance, value to ecotourism, high price into the western market and sensitivity to habitat degradation there have been few conservation studies in western Madagascar. Information on chameleon distribution comes mainly from herpetological inventories (e.g. Raxworthy and Nussbaum, 1996; Andreone and Randriamahazo, 1997; Bora *et al*., 2007). Other studies that focus on chameleons have reported on taxonomy (Glaw *et al*., 1999; Raxworthy and Nussbaum, 2006), biology and evolution (Raxworthy, 1991; 1995; 2003), habitat use (Brady *et al*., 1996; Jenkins *et al*., 2003; Randrianantoandro *et al*., 2007), behaviour (Kauffmann *et al*., 1997) and trade (e.g. Brady and Griffiths, 1999; Carpenter and Robson, 2005). Most of chameleon studies were undertaken within the eastern rain forests (Brady and Griffiths, 1999). Even though many chameleon species are restricted to forests there are few monitoring programmes and only in Tsingy de Bemaraha National Park are they classed as a priority taxon.

The aims of this study were to assess the distribution, structure, and abundance of chameleon populations across a gradient of habitat degradation in central Menabe; to identify key sites for chameleon conservation; determine which species are most likely to be impacted by habitat change and to develop a simple, repeatable monitoring protocol for use by the future management team in the new protected area.

## STUDY SITE

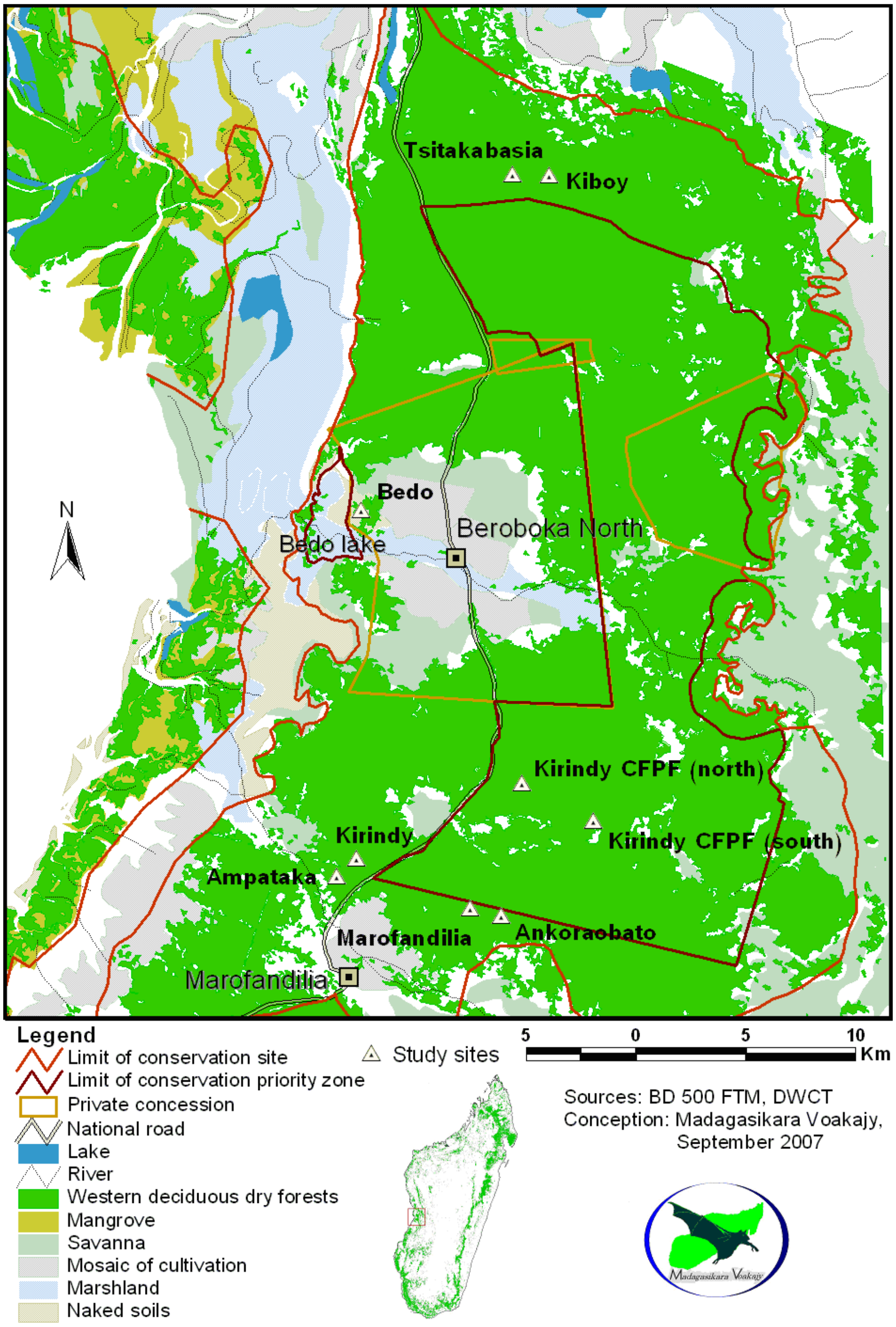
The Menabe region encloses one of the largest remaining dry forests in western Madagascar (Nelson and Horning, 1993). The climate of the central Menabe is classified as tropical dry with two distinct seasons: a hot wet season between November and March/April and a cooler dry season from May to August. The time of transition in October and November is already fairly hot with some rain. Most of the yearly rain falls between January to February, and the mean annual rainfall averaged 767 mm/year between 1906 and 1993 (Sorg *et al.*, 2003). Study sites were located about 7 to 20 km east of the coast and 30 to 70 km northeast of Morondava (Figure 1). Elevation ranges between 20 to 113 m a.s.l. (Table 1).

In the protected area of central Menabe which contains 100,000 ha of dry forests, nine sites were selected to represent different types of vegetation structure. Chameleons were surveyed in areas subject to high and low disturbance in each site. These sites were selected with the recommendations of DWCT staff.

All field work was undertaken from late January to the beginning of April 2007.

**Table 1.** Geographical coordinates of study sites. $n_{ft}$: number of random forest transects in each site.

| Study site | $n_{ft}$ | Altitude (m) a.s.l. | Latitude S | Longitude E | Date of observation |
|---|---|---|---|---|---|
| Kirindy CFPF (south) | 14 | 76 | 20°07’28.5’’ | 044°66’28.7’’ | 27/01/07 - 05/02/07 |
| Kiboy | 12 | 113 | 19°80’49.7’’ | 044°63’86.3’’ | 07/02/07 - 22/02/07 |
| Tsitakabasia | 12 | 102 | 19°80’35.4’’ | 044°63’01.4’’ | 07/02/07 - 22/02/07 |
| Ampataka | 9 | 20 | 20°08’96.5’’ | 044°54’84.9’’ | 24/02/07 - 07/03/07 |
| Kirindy | 9 | 29 | 20°08’44.8’’ | 044°55’25.9’’ | 24/02/07 - 07/03/07 |
| Marofandilia | 9 | 57 | 20°10’16.0’’ | 044°60’87.1’’ | 08/03/07 - 19/03/07 |
| Ankoraobato | 9 | 67 | 20°10’48.7’’ | 044°61’61.6’’ | 08/03/07 - 19/03/07 |
| Bedo | 12 | 20 | 19°93’80.0’’ | 044°55’71.4’’ | 20/03/07 - 27/03/07 |
| Kirindy CFPF (north) | 6 | 49 | 20°05’23.0’’ | 044°63’36.5’’ | 28/03/07 - 01/04/07 |



Sources: BD 500 FTM, DWCT
Conception: Madagasikara Voakajy,
September 2007

**Figure 1.** Location of study sites.

## METHODS

Within each forest area we surveyed chameleons along existing trails and on random transects in the forest. Although random transects are statistically preferable, forest trails facilitate easy and rapid access for survey teams. Trail transect had a total length of 450 m. Along each trail, 6 random transects were established. Transects of 150 m (3 lines x 50) running off each trail in random directions were used. The starting point of each transect was located 5–8 m into the forest from the nearest trail. One to two trails per site were inspected. Each transect was searched only once.

Chameleons are diurnal insectivores and very difficult to find during the day because of their camouflage and slow movement. At night however, they roost on vegetation and can be easily detected with a head-torch (Jenkins *et al.*, 1999). Surveyors (working in teams of two) moved slowly along each transect searching opposite flanks for roosting chameleons with the aid of Petzl myo xp head torches. For each encountered animal we measured the perpendicular distance from the transect line. Population densities were calculated using the computer program DISTANCE (version 4.1 Release 2) (Thomas *et al.* 2004). The program fits a series of functions to the distance data and the model best fitting the data was selected by the Akaike Information Criterium (Buckland *et al*. 2001). Our vertical ceiling was 7 m rather than 6 m, as used in other studies (Jenkins *et al.*, 1999; Jenkins *et al*., 2003; Andreone *et al.*, 2005) because the vegetation is more open in the dry deciduous forests. The horizontal or perpendicular distance data were truncated at 5 m for *Brookesia* and 6 m for *Furcifer* which has a larger body size and can be easily found at this distance from the line in the forest at Menabe. Hatchling chameleons were excluded from the analysis. More details on survey methodology are given in Brady & Griffiths (1999) and Jenkins *et al.* (2003).

Abundance was represented as the number of individuals observed per 100 m. The roosting (perch) height and height of the plant used by each chameleon was also measured. A range of morphometric measurements were taken on a representative sample of all chameleon species encountered to determinate the population structure. The chameleon roosting perches were marked each night with a colored tag and returned to the site the following morning where a quadrat (plot) of 5 x 5 m was placed on the ground with the perch at the centre. We also assessed the microhabitat within a quadrat for each transect line in area where no chameleons were located during the night giving us data from areas with and without roosting chameleons. Within these quadrats we recorded 14 microhabitat variables: canopy cover (%), understorey cover (%) occurring in the lower 2 m stratum of the forest, numbers of trees (big, large and small) and cut tree by human, litter depth (cm), litter cover (%), canopy high (m), liane index (0: absent, 1: rare; 2: present and 3: frequent). Using a 1 m stick marked with centimeter gradations, we recorded whether there was contact with ground vegetation in four height categories (0-0.24 m, 0.25-0.49 m, 0.50-0.74 m and 0.75-1.0 m) every 25 cm along two 5 m lines with the perch at the centre in the quadrat.

Chameleon diet was assessed by collecting faecal samples from animals kept overnight in cloth bags. Fragments of invertebrates were later removed from the pellets under a low power microscope in a laboratory (Hofer *et al*., 2003). We estimated percentage frequency for all prey to order. The prey availability was investigated by sweeping vegetation with nets to a height of 1.5 m at or near sites where chameleons were located. These samples were helpful in identifying remnants in the pellets and used as rough estimates of prey availability within each habitat type.

ANOVA (Statview v. 5.0; SAS, 1998) was used to compare roost height of chameleon species between habitats. One-way ANOVA was used to test for significant differences between chameleon abundance index and habitats, vegetation characteristics habitat features at each site and for comparisons of measured or log transformed variables between quadrats with and without chameleons. Post-hoc tests (Fisher's PLSD) were used to determine the significance of pairwise comparaisons. Kruskal Wallis test and Spearman correlation were used with non-parametric data.

## RESULTS

Chameleons were observed on 92 forest and 15 path transects, giving a total effort of 20.8 km. A total of 671 chameleons from four species were detected along all transects. *Brookesia brygooi* was the most abundant with 492 observations, followed by *F. labordi* (90), *F. nicosiai* (70), and *F. oustaleti* was the rarest with 19 observations.

The calculated densities of *Brookesia brygooi* and *Furcifer* spp. encountered within the study sites are shown in Table 2. *Brookesia brygooi* was more abundant (35.5 ha$^{-1}$) than *Furcifer* spp. (12.7 ha$^{-1}$) across all study sites. The densities of *B. brygooi* varied between 3.7 ha$^{-1}$ in Bedo baobab forest and 92.1 ha$^{-1}$ in Tsitakabasia-Kiboy forests. However, *Furcifer* spp. were most abundant (20.5 ha$^{-1}$) in Bedo baobab forest and were very rare (0.7 ha$^{-1}$) in Ankoraobato-Marofandilia forests. The density of each *Furcifer* species within each study site was impossible to calculate by the program DISTANCE because of the low number of chameleon observations.

**Table 2.** DISTANCE calculated densities (ha$^{-1}$) for chameleon populations surveyed at central Menabe during January to April 2007. *Furcifer* represent pooled estimates for all species. The densities of rarely encountered species were associated with very high % CV.

| Site (Survey effort) | Species | DISTANCE Selected Model | D (ha$^{-1}$) | n | % C.V. | 95 % I.C. |
|---|---|---|---|---|---|---|
| Kirindy CFPF (4,500 m) | *B. brygooi* | Uniform | 35.0 | 77 | 16.2 | 25.2 – 48.7 |
| | *Furcifer* spp. | Hazard | 17.6 | 47 | 23.6 | 10.9 – 28.3 |
| Tsitakabasia-Kiboy (5,550 m) | *B. brygooi* | Uniform | 92.1 | 334 | 13.6 | 70.4 – 120.5 |
| | *Furcifer* spp. | Uniform | 15.1 | 41 | 20.5 | 10.0 – 22.9 |
| Ankoraobato-Marofandilia (4,050 m) | *B. brygooi* | Uniform | 9.0 | 23 | 32.5* | 4.7 – 17.3 |
| | *Furcifer* spp. | Half-normal | 0.7 | 12 | 267.9* | 0.0 – 17.5 |
| Kirindy-Ampataka (4,050 m) | *B. brygooi* | Uniform | 6.0 | 15 | 43.4* | 2.5 – 14.2 |
| | *Furcifer* spp. | Uniform | 6.2 | 18 | 23.9 | 3.8 – 10.1 |
| Bedo (2,700 m) | *B. brygooi* | Uniform | 3.7 | 10 | 71.0 | 0.9 – 14.7 |
| | *Furcifer* spp. | Uniform | 20.5 | 37 | 22.7 | 12.8 – 33.0 |
| Total (20,843.2 m) | *B. brygooi* | Half-normal | 35,5 | 460 | 15.1 | 26.4 – 47.8 |
| | *Furcifer* spp. | Uniform | 12.7 | 155 | 11.8 | 10.1 – 16.1 |

*: C.V. above the threshold of 30 % recommended by Brady and Griffiths (1999).

**Figure 2.** Flat-tailed tortoise: *Pyxis planicauda* **(A)**. Bedo baobab forest **(B)**. Transport to Bedo camp site **(C)**. Burnt area in Tsitakabasia forest **(D)**. Nocturnal transect survey **(E)** (photographs by Christian J. Randrianantoandro).

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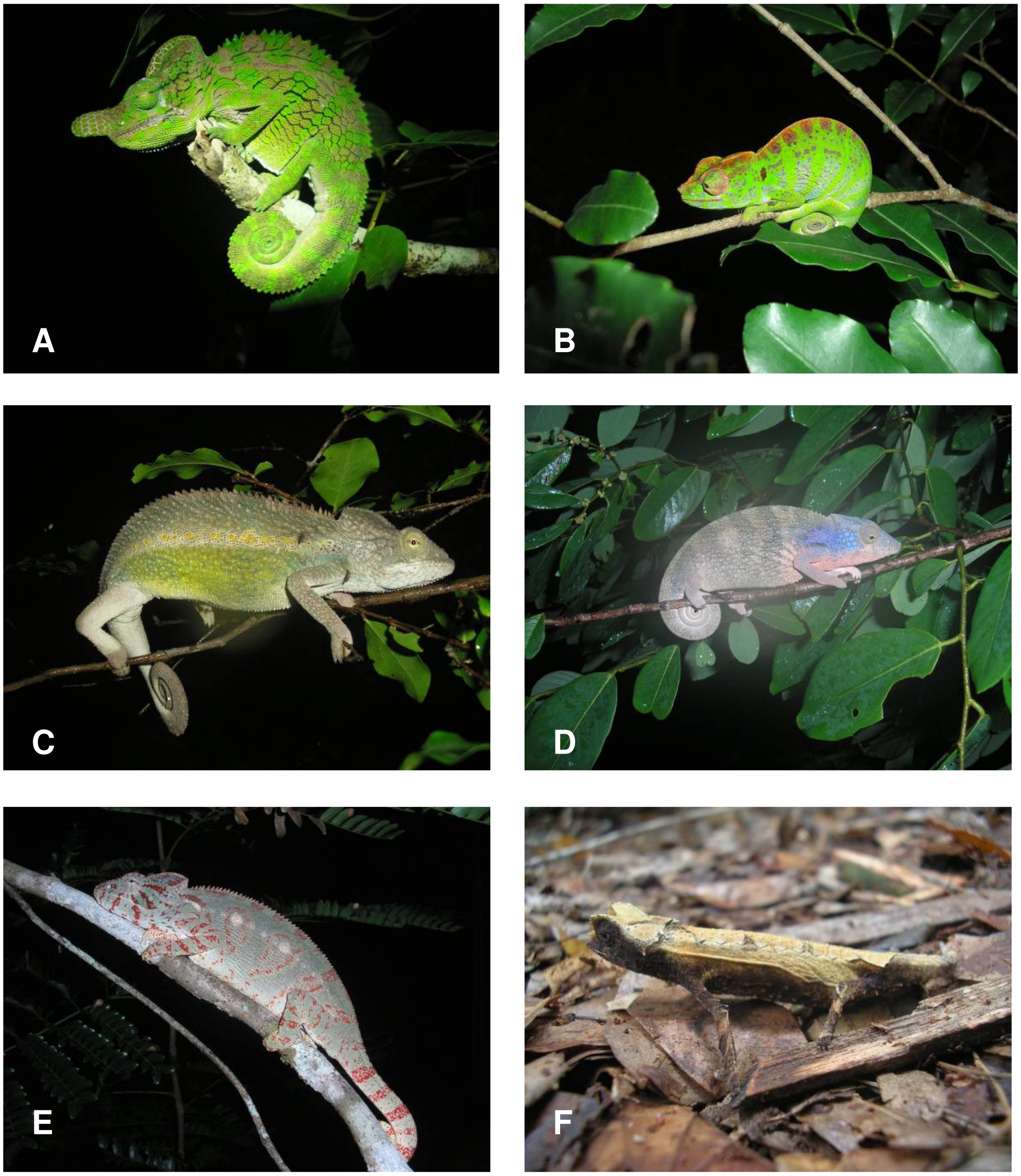

**Figure 3.** Male 150-289 mm TL **(A),** and female 119-168 mm TL **(B)** of *Furcifer labordi* from central Menabe. Males are characterized by the presence of a single rostral appendage, a high casque, a weakly developed dorsal crest, and canthi rostrals are very distinct. Females have a rostral appendage rudimentary, sometimes very colourful, often with red colour on the throat, two small, red, lateral markings on the neck, and orange vertebral markings. In most females violaceous-blue colouration is present on the flanks. Male 221-320 mm TL **(C),** and female 167-223 mm TL **(D)** of *Furcifer nicosiai*. Males have a head, body and tail whitish with diffused brown marbling, a large white stripe along flanks, and several dark cross bands laterodorsally on body and tail; canthi rostrales well developed and separated. Large rounded scales in parietal and temporal regions, between canthi rostrales and between orbital crests. Females coloration are extremely peculiar, including various shadings of light blue and violet, a pink stripe along flanks interrupted by a few bluish cross bands. *Furcifer oustaleti* female 231-340 mm TL (male 190-225 mm) **(E),** and *B. brygooi* male 42-78 mm TL (female 38-81 mm) **(F)** (photographs by Christian J. Randrianantoandro).

A total of 13.9 km of forest transects were surveyed during this study, with 6.1 km in low-disturbance forest and 7.8 km in high-disturbance forest. The estimated densities for each chameleon species within each habitat type are shown in table 4. It appears that chameleons were more abundant in dry deciduous forest subject to low-disturbance than in patches of high-disturbance. Therefore, these species can be used as indicators of the forest disturbance.

### *Brookesia brygooi*

*Brookesia brygooi* was the most abundant chameleon species encountered in central Menabe during this study. This species was encountered at all sites between 20 and 113 m of elevation and was found principally along the forest transects. Its abundance was highest 8.44 ± 0.6 individuals per 100 m and 7.44 ± 1.0 individuals per 100 m across the forest transects in Kiboy and Tsitakabasia forests. These sites are situated in the north part of the central Menabe and represented the highest elevation. The lowest abundance was observed in Ampataka forest (0.44 ± 0.3 individual per 100 m). The density and abundance of *B. brygooi* was affected by forest disturbance. It was most abundant in forest subject to low-disturbance (4.42 ± 0.6 individuals per 100 m, 66.5 ha$^{-1}$).

The distribution area of *B. bygooi* includes western deciduous forests within the latitudinal range 17-23°S.

### *Furcifer labordi*

*Furcifer labordi* was found within all study sites. The calculated density of this species in central Menabe was 7.17 individuals per hectare. The highest abundance was 0.94 ± 0.2 individual per 100 m in Bedo baobab forest and followed by the path in Kirindy CFPF forest (0.89 ± 0.1 individuals per 100 m). The abundance along trails and forest transects varied between sites. The abundance index of *F. labordi* was different between disturbance levels: this species was abundant in low-disturbance (14.4 ha$^{-1}$) and became rare (3.5 ha$^{-1}$) in high-disturbance forest. The abundance of *F. labordi* was also affected by forest disturbance.

### *Furcifer nicosiai*

This chameleon species was encountered in all sites except Bedo baobab forest. The calculated density of *F. nicosiai* was 2.99 individuals per hectare in the central Menabe. Generally, this taxon was more frequently encountered across the forest transects in central Menabe (except Marofandilia and Tsitakabasia) with the highest abundance (0.94 ± 0.2 individual per 100 m) in Kiboy followed by the trail in Tsitakabasia forest. *Furcifer nicosiai* was also affected by forest disturbance. The abundance was high 3.3 ha$^{-1}$ in less-disturbance forest.

### *Furcifer oustaleti*

*Furcifer oustaleti* was the rarest species encountered in central Menabe during this study and wasn't recorded in Kirindy CFPF and Ankoraobato, Marofandilia and Kirindy forests. Some individuals were observed outside the transects in Kirindy CFPF forest. It was recorded mainly across the random transects with the highest abundance (0.61 ± 0.1 individual per 100 m) along that of Bedo baobab forest. *Furcifer oustaleti* was also affected by forest disturbance. Its calculated density was low (0.3 ha$^{-1}$) as well as forests were highly disturbed.

**Table 3.** Abundance (per 100 m) ± standard error (S.E.) and (n) number of individuals encountered in central Menabe from January to April 2007.

| | ***Brookesia brygooi*** | | ***Furcifer nicosiai*** | | ***Furcifer labordi*** | | ***Furcifer oustaleti*** | |
|---|---|---|---|---|---|---|---|---|
| | Forest Transect | *Path Transect* | Forest Transect | *Path Transect* | Forest Transect | *Path Transect* | Forest Transect | *Path Transect* |
| Kirindy CFPF | 2.21 ± 0.4<br>(68) | *1.33 ± 0.3*<br>*(18)* | 0.38 ± 0.1<br>(12) | *0.37 ± 0.1*<br>*(5)* | 0.71 ± 0.1<br>(23) | *0.89 ± 0.1*<br>*(12)* | 0.00<br>(0) | *0.00**<br>*(0)* |
| Kiboy | 8.44 ± 0.6<br>(152) | *3.11 ± 0.4*<br>*(29)* | 0.94 ± 0.2<br>(17) | *0.44 ± 0.2*<br>*(4)* | 0.33 ± 0.1<br>(6) | *0.59 ± 0.1*<br>*(5)* | 0.16 ± 0.1<br>(3) | *0.00*<br>*(0)* |
| Tsitakabasia | 7.44 ± 1.0<br>(134) | *3.18 ± 0.5*<br>*(30)* | 0.62 ± 0.1<br>(11) | *0.74 ± 0.5*<br>*(6)* | 0.16 ± 0.1<br>(3) | *0.15 ± 0.1*<br>*(2)* | 0.00<br>(0) | *0.11 ± 0.1*<br>*(1)* |
| Ankoraobato | 1.40 ± 0.4<br>(19) | *0.11 ± 0.1*<br>*(1)* | 0.22 ± 0.1<br>(3) | *0.00*<br>*(0)* | 0.14 ± 0.1<br>(2) | *0.55 ± 0.3*<br>*(3)* | 0.00<br>(0) | *0.00*<br>*(0)* |
| Marofandilia | 0.74 ± 0.2<br>(10) | *0.22 ± 0.2*<br>*(2)* | 0.14 ± 0.1<br>(2) | *0.22 ± 0.2*<br>*(1)* | 0.29 ± 0.1<br>(4) | *0.00*<br>*(0)* | 0.00<br>(0) | *0.00*<br>*(0)* |
| Ampataka | 0.44 ± 0.3<br>(6) | *0.00*<br>*(0)* | 0.07 ± 0.1<br>(1) | *0.00*<br>*(0)* | 0.29 ± 0.1<br>(4) | *0.11 ± 0.1*<br>*(1)* | 0.14 ± 0.1<br>(2) | *0.11 ± 0.1*<br>*(1)* |
| Kirindy | 0.66 ± 0.3<br>(9) | *0.33 ± 0.3*<br>*(3)* | 0.44 ± 0.2<br>(6) | *0.22 ± 0.2*<br>*(2)* | 0.22 ± 0.1<br>(3) | *0.55 ± 0.1*<br>*(4)* | 0.00<br>(0) | *0.00*<br>*(0)* |
| Bedo | 0.55 ± 0.3<br>(10) | *0.11 ± 0.1*<br>*(1)* | 0.00<br>(0) | *0.00*<br>*(0)* | 0.94 ± 0.2<br>(17) | *0.11 ± 0.1*<br>*(1)* | 0.61 ± 0.1<br>(11) | *0.11 ± 0.1*<br>*(1)* |
| Ensemble | 2.94 ± 0.3<br>(408) | *1.28 ± 0.3*<br>*(84)* | 0.37<br>(52) | *0.29 ± 0.1*<br>*(18)* | 0.43 ± 0.1<br>(62) | *0.45 ± 0.1*<br>*(28)* | 0.11 ± 0.0<br>(16) | *0.04*<br>*(3)* |

*: species found outside the transect.

**Table 4.** DISTANCE calculated densities (ha$^{-1}$) for chameleon species surveyed along forest type at central Menabe during January to April 2007. (*): C.V. above the threshold of 30 % recommended by Brady and Griffiths (1999).

| **Forest type (Sites)** | **Species** | **Abundance (/ 100 m) ± S.E.** | **DISTANCE Selected Model** | **D (ha$^{-1}$)** | **n** | **% C.V.** | **95% I. C.** |
|---|---|---|---|---|---|---|---|
| **Low-disturbance** (Kirindy CFPF; Tsitakabasia; kiboy; Ankoraobato; Bedo) | *B. brygooi* | 4.42 ± 0.63 | Hazard | 66.5 | 247 | 14.5 | 49.7 – 88.9 |
| | *F. labordi* | 0.67 ± 0.11 | Half-normal | 14.4 | 40 | 20.4 | 9.6 – 21.5 |
| | *F. nicosiai* | 0.44 ± 0.08 | Uniform | 3.3 | 15 | 55.2* | 1.1 – 9.7 |
| | *F. oustaleti* | 0.16 ± 0.06 | Half-normal | 3.4 | 10 | 50.69 | 1.3 – 9.0 |
| **High-disturbance** (Kirindy CFPF; Tsitakabasia; Kiboy; Ankoraobato; Marofandilia; Kirindy; Ampataka; Bedo) | *B. brygooi* | 1.80 ± 0.37 | Uniform | 31.7 | 127 | 23.0 | 20.1 – 50.0 |
| | *F. labordi* | 0.25 ± 0.05 | Uniform | 3.5 | 20 | 26.7 | 2.1 – 6.0 |
| | *F. nicosiai* | 0.32 ± 0.08 | Half-normal | 1.7 | 12 | 86.4* | 0.3 – 8.8 |
| | *F. oustaleti* | 0.07 ± 0.03 | Uniform | 0.3 | 7 | 139.7 | 0.2E-01 – 5.0 |

### *Habitat characteristics*

ANOVA comparisons shown that habitat variables collected from quadrats were significantly different between sites. The high percentage of canopy cover (54.4 ± 1.62) and high canopy height (10.6 ± 0.40) which characterized low-disturbance forests, were observed in Tsitakabasia, kiboy, Kirindy CFPF and Bedo forests. Litter depth and number of small trees were also important in less disturbed forests. Post-hoc tests (Fisher's PLSD) revealed significant differences between the means percentage of canopy cover between Kirindy-Ampataka and Kirindy CFPF forests, Kirindy-Ampataka and Tsitakabasia-kiboy forests. A highly disturbed area like Kirindy-Ampataka forests were characterized by high number of cut trees by humans (0.18 ± 0.05) and a high percentage understorey cover which is associated with the high vegetations 0 to 1 m above the forest floor. Some highly disturbed patches in sites situated at the north of central Menabe were characterized by a lower abundance of big trees. Bedo forest was characterized by a low understorey cover and a high number of big tree due to the abundance of baobab trees (Tables 5 and 6).

### *Habitat preferences*

The abundance of *B. brygooi* was significantly different between habitats ($F_1$ = 13.9, $P$ <0.001), with low-disturbance forest showing the highest abundance and the lowest was observed in the high-disturbance forest. Forest disturbance significantly affected the abundance of *F. labordi* ($F_1$ = 12.84, $P$ < 0.001). This species was most abundant in low-disturbance and was rarest in high-disturbance forests.

Most of the variables recorded were not significantly different between plots with or without chameleon species. Significant differences were found only on the means number of small tree, liane index and the vegetation situated at 0 to 0.24 m above the forest floor. Post-hoc tests (Fisher's PLSD) showed the significant differences on the vegetation 0-0.24 m above the forest floor between quadrats with *B. brygooi*, *F. labordi*, *F. oustaleti* and no chameleon. It seems that this variable was highest in quadrats with *B. brygooi* and *F. nicosiai* (Table 7). The largest chameleon *F. oustaleti* was found in quadrat where this vegetation was lowest as the mean perch height of this species was highest than the others species. The dwarf chameleon *B. brygooi* preferred the forest with a high canopy cover, high understorey cover, and high litter depth which correspond generally to the structure of less-disturbance forest.

**Table 5.** Means values for each of the measured habitat variables, and comparisons (*t*-tests for paired comparisons) of combined "less-disturbance" and "high-disturbance" data. Significance at the $P < 0.05$ level is indicated (*); $P < 0.0001$ level is indicated (**).

| Habitat | Means ± S.E.<br>Less-disturbance | <br>High-disturbance | *t* |
|---|---|---|---|
| Canopy cover (%) | 54.4 ± 1.62 | 49.3 ± 2.15 | $1.80^{n.s.}$ |
| Understorey cover (%) | 42.1 ± 1.88 | 42.5 ± 1.71 | $-0.16^{n.s}$ |
| Litter cover (%) | 85.6 ± 0.71 | 85.1 ± 0.59 | $0.48^{n.s}$ |
| Litter depth (cm) | 3.0 ± 0.23 | 1.5 ± 0.07 | 7.12** |
| Big tree (n) | 0.14 ± 0.02 | 0.11 ± 0.02 | $0.77^{n.s}$ |
| Large tree (n)$^{a}$ | 0.83 ± 0.13 | 0.79 ± 0.06 | $-0.82^{n.s}$ |
| Small tree (n)$^{a}$ | 46.79 ± 3.42 | 31.21 ± 0.95 | 4.47*** |
| Cut tree by human (n) | 0.03 ± 0.01 | 0.18 ± 0.05 | -2.55* |
| Liane index | 1.6 ± 0.12 | 1.3 ± 0.08 | $1.83^{n.s}$ |
| Canopy height (m) | 10.6 ± 0.40 | 8.2 ± 0.24 | 5.28*** |
| Vegetation (0 – 0.24 m) | 3.0 ± 0.25 | 3.3 ± 0.19 | $-0.38^{n.s}$ |
| Vegetation (0.25 – 0.49 m) | 2.5 ± 0.15 | 3.0 ± 0.11 | -2.62* |
| Vegetation (0.50 – 0.74 m) | 2.3 ± 0.12 | 3.1 ± 0.14 | -3.88** |
| Vegetation (0.75 - 1 m) | 2.4 ± 0.12 | 2.8 ± 0.13 | -2.27* |

$^{a}$: Transformation logarithmic

**Table 6.** Means (± S.E.) of variables habitats characteristics in each site. ANOVA results comparison were shown and post-hoc tests were used to determine which variables shown a significant difference. The superscript counts represent the significant differences from post-hoc tests (Fisher's PSLD).

| Habitat | Ampataka-Kirindy | Bedo | Marofandilia-Ankoraobato | Kirindy CFPF | Tsitakabasia-Kiboy | *F* | *P* |
|---|---|---|---|---|---|---|---|
| Canopy cover (%) | $44.7 \pm 3.85^{1}$ | 52.2 ± 3.46 | $47.7 \pm 2.54^{2}$ | $53.1 \pm 2.23^{1}$ | $57.5 \pm 2.05^{12}$ | 3.54 | < 0.05 |
| Understorey cover (%) | $40.4 \pm 2.13^{1}$ | $23.8 \pm 2.06^{12}$ | $51.3 \pm 2.11^{1234}$ | $45.6 \pm 1.90^{23}$ | $43.5 \pm 1.27^{24}$ | 22.57 | < 0.0001 |
| Litter cover (%) | $86.2 \pm 0.77^{1}$ | $87.7 \pm 0.54^{2}$ | $81.5 \pm 1.45^{12}$ | 84.4 ± 1.09 | $84.2 \pm 1.16^{2}$ | 3.55 | < 0.05 |
| Litter depth (cm) | $1.6 \pm 0.0^{1}$ | $1.1 \pm 0.0^{12}$ | $1.1 \pm 0.0^{1234}$ | $3.6 \pm 0.1^{123}$ | $2.4 \pm 0.0^{1234}$ | 85.52 | < 0.0001 |
| Big tree (n) | 0.1 ± 0.05 | $0.2 \pm 0.04^{1}$ | $0.08 \pm 0.03^{1}$ | 0.1 ± 0.04 | $0.05 \pm 0.01^{1}$ | 2.73 | < 0.05 |
| Large tree (n) | 0.7 ± 0.07 | $0.3 \pm 0.06^{1}$ | $0.9 \pm 0.09^{1}$ | $0.9 \pm 0.18^{1}$ | $0.9 \pm 0.17^{1}$ | 2.64 | < 0.05 |
| Small tree (n) | $31.4 \pm 1.03^{1}$ | $31.0 \pm 1.30^{2}$ | $27.4 \pm 1.56^{34}$ | $54.9 \pm 3.77^{123}$ | $36.5 \pm 3.64^{34}$ | 14.00 | < 0.0001 |
| Cut tree by human (n) | $0.5 \pm 0.11^{1}$ | $0.03 \pm 0.02^{1}$ | $0.02 \pm 0.01^{1}$ | 0.04 ± 0.01 | $0.1 \pm 0.03^{1}$ | 17.36 | < 0.0001 |
| Liane index | $0.9 \pm 0.03^{1}$ | $0.9 \pm 0.02^{2}$ | $1.4 \pm 0.08^{124}$ | $1.2 \pm 0.04^{13}$ | $2.3 \pm 0.11^{1234}$ | 54.13 | < 0.0001 |
| Canopy height (m) | $8.9 \pm 0.4^{1}$ | $8.0 \pm 0.35^{2}$ | $7.6 \pm 0.32^{134}$ | $11.7 \pm 0.54^{123}$ | $9.4 \pm 0.36^{234}$ | 14.53 | < 0.0001 |
| Vegetation (0 – 0.24 m) | $2.7 \pm 0.24^{1}$ | $1.5 \pm 0.25^{12}$ | $3.2 \pm 0.19^{234}$ | $2.6 \pm 0.25^{23}$ | $4.7 \pm 0.19^{1234}$ | 24.90 | < 0.0001 |
| Vegetation (0.25 – 0.49 m) | $2.9 \pm 0.17^{1}$ | $1.4 \pm 0.13^{12}$ | $3.4 \pm 0.12^{1234}$ | $2.5 \pm 0.18^{23}$ | $2.8 \pm 0.14^{234}$ | 16.03 | < 0.0001 |
| Vegetation (0.50 – 0.74 m) | $3.6 \pm 0.21^{1}$ | $1.5 \pm 0.12^{12}$ | $3.0 \pm 0.19^{1234}$ | $2.3 \pm 0.17^{123}$ | $2.5 \pm 0.14^{124}$ | 15.40 | < 0.0001 |
| Vegetation (0.75 - 1 m) | $3.3 \pm 0.18^{1}$ | $1.9 \pm 0.22^{1}$ | $2.3 \pm 0.13^{1}$ | $2.4 \pm 0.17^{1}$ | $2.3 \pm 0.14^{1}$ | 9.01 | < 0.0001 |

**Table 7.** Variables means (± S.E.) of habitats recorded within quadrats with or without chameleon in Menabe. Significant differences were revealed by post-hoc tests (Fisher's PLSD).

| **Variables** | ***Brookesia brygooi* (n = 110)** | ***Furcifer labordi* (n = 73)** | ***Furcifer nicosiai* (n = 38)** | ***Furcifer oustaleti* (n = 14)** | **No chameleon (n = 317)** | ***P*-value** |
|---|---|---|---|---|---|---|
| Canopy cover %) | 54.3 ± 2.56 | 54.4 ± 2.7 | 53.2 ± 4.2 | 49.2 ± 7.5 | 50.8 ± 1.4 | n.s.$^{a}$ |
| Understorey cover (%) | 43.5 ± 1.4 | 39.7 ± 2.1 | 42.2 ± 3. 16 | 35.0 ± 5.6 | 42.6 ± 1.0 | n.s.$^{a}$ |
| Litter cover (%)* | 85.9 ± 0.5 | 84.9 ± 1.2 | 83.1 ± 1.2 | 86.7 ± 1.4 | 84.2 ± 0.5 | n.s.$^{a}$ |
| Litter depth (cm) | 2.4 ± 0.1 | 2.3 ± 0.2 | 2.0 ± 0.1 | 1.9 ± 0.3 | 2.1 ± 0.0 | n.s.$^{b}$ |
| Big tree (n) | 0.0 ± 0.0 | 0.1 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.1 ± 0.0 | n.s.$^{b}$ |
| Large tree (n)* | 0.8 ± 0.0 | 0.6 ± 0.1 | 1.0 ± 0.2 | 0.2 ± 0.1 | 0.8 ± 0.0 | n.s.$^{a}$ |
| Small tree (n)* | 39.3 ± 2.1$^{1}$ | 40.9 ± 2.6$^{23}$ | 32.8 ± 3.9$^{124}$ | 28.5 ± 3.1$^{3}$ | 37.1 ± 1.1$^{4}$ | < 0.05 $^{a}$ |
| Cut tree by human (n) | 0.6 ± 0.0a | 0.1 ± 0.0 | 0.1 ± 0.0 | 0.07 ± 0.0 | 0.1 ± 0.0 | n.s.$^{b}$ |
| Liane index | 1.8 ± 0.0$^{1}$ | 1.2 ± 0.0$^{12}$ | 1.5 ± 0.1$^{2}$ | 1.4 ± 0.2 | 1.4 ± 0.0$^{1}$ | < 0.0001$^{a}$ |
| Canopy height (m) | 9.4 ± 0.3 | 9.7 ± 0.4 | 9.0 ± 0.5 | 8.7 ± 0.6 | 9.2 ± 0.1 | n.s.$^{a}$ |
| Vegetation (0 – 0.24 m) | 3.7 ± 0.1$^{1}$ | 3.0 ± 0.2$^{12}$ | 3.7 ± 0.3$^{3}$ | 1.8 ± 0.4$^{1234}$ | 3.1 ± 0.1$^{14}$ | < 0.001$^{a}$ |
| Vegetation (0.25 – 0.49 m) | 2.8 ± 0.1$^{1}$ | 2.4 ± 0.1$^{1}$ | 2.8 ± 0.2 | 2.1 ± 0.3 | 2.7 ± 0.0 | n.s.$^{a}$ |
| Vegetation (0.50 – 0.74 m) | 2.9 ± 0.1$^{1}$ | 2.6 ± 0.1 | 2.9 ± 0.2 | 2.6 ± 0.3 | 2.5 ± 0.0$^{1}$ | n.s.$^{a}$ |
| Vegetation (0.75 – 1 m) | 2.6 ± 0.1 | 2.4 ± 0.1 | 2.3 ± 0.2 | 2.5 ± 0.4 | 2.4 ± 0.0 | n.s.$^{a}$ |

$^{a}$: ANOVA test
$^{b}$: Kruskal Wallis test
*: Transformation logarithmic

Chameleon abundance were significantly correlated with the transect elevation. The abundance, of *B. brygooi* and *F. nicosiai* were significantly and positively correlated with the altitude (*Rho* = 0.719 and $P < 0.0001$; *Rho* = 0.441 and $P < 0.0001$). The abundance of *F.* labordi and *F. oustaleti* were significantly negatively correlated (*Rho* = -0.262 and $P < 0.05$ and *Rho* = -0.280 and $P < 0.05$). Chameleon abundance was therefore affected by small gradient of elevation in central Menabe.

Nocturnal perch heights were significantly different between species and habitats (Figures 4a and 4b; Tables 8 and 9). The highest perch and plant height with roost of *Brookesia brygooi* and *Furcifer* spp. were observed in low-disturbance forests. The means perch height of *F. labordi* encountered during this study was 1.8 ± 0.0 m in low-disturbance and 1.6 ± 0.2 m in high-disturbance forests.

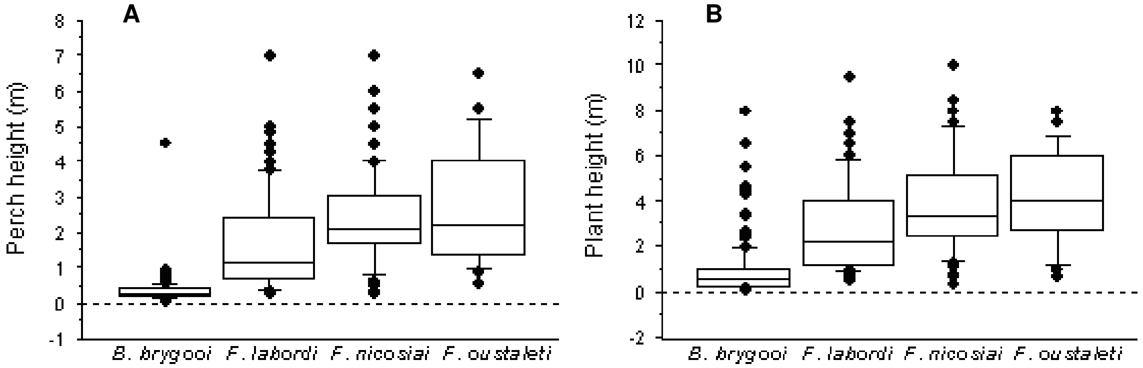

**Figure 4.** Characteristics of roost sites for all species **(A)** perch height **(B)** plant height with roost.

The perch height was significantly different between habitats (low and high-disturbance forests) and chameleon species, with a significant interaction between the two. The roost height of *B. brygooi* was significantly lower than *F. labordi*, *F. nicosiai* and *F. oustaleti* across all habitats.

**Table 8.** Means (± S.E.) perch and plant height with roost of chameleon species within habitat type.

| | **Perch height (m) ± S.E.** | | **Plant height (m) ± S.E.** | |
|---|---|---|---|---|
| **Species** | **Low disturbance** | **High disturbance** | **Less disturbance** | **High disturbance** |
| *Brookesia brygooi* | 0.36 ± 0.0 | 0.28 ± 0.0 | 0.9 ± 0.1 | 0.7 ± 0.1 |
| *Furcifer labordi* | 1.8 ± 0.0 | 1.6 ± 0.2 | 3.0 ± 0.3 | 2.5 ± 0.4 |
| *Furcifer nicosiai* | 2.4 ± 0.2 | 2.1 ± 0.2 | 4.1 ± 0.5 | 3.2 ± 0.3 |
| *Furcifer oustaleti* | 3.6 ± 0.5 | 1.9 ± 0.5 | 5.0 ± 0.5 | 3.4 ± 0.9 |

**Table 9.** Summary of ANOVA comparison of the perch height of chameleon species in habitat types (low and high-disturbance forests).

| | **DF** | **Sum of Squares** | **Mean Square** | ***F*-Value** | ***P*-Value** |
|---|---|---|---|---|---|
| Species | 3 | 197.167 | 65.722 | 65.48 | < 0.0001 |
| Habitat | 1 | 11.866 | 11.866 | 11.82 | < 0.001 |
| Species * Habitat | 3 | 8.794 | 2.931 | 2.9 | < 0.05 |
| Residual | 256 | 256.940 | 1.004 | | |

In general, the perch height was affected by the chameleon body size. A non-parametric Spearman correlation revealed the strong positive association between the roost height and the body weight (*Rho* = 0.545 and *P* < 0.0001); and between the roost height and snout-vent length (*Rho* = 0.651 and *P* < 0.0001). The largest and arboreal species (*Furcifer)* roosted higher than the smaller dwarf chameleons (*Brookesia*).

### *Population structure*

Chameleon populations were structured with distinct life-stage groupings, which can be categorized into three main stages: hatchling, juvenile and adult. Growth curves illustrating these life-stages are shown in Figure 5. No hatchlings were observed for *F. labordi* and *F. oustaleti*. For *B. brygooi* and *F. nicosiai*, hatchlings begun to emerge during April. The population of *F. oustaleti* contained a high number of juveniles and that of *F. nicosiai* was observed with more hatchlings. Females were numerous than males in the chameleon community with the exception of *F. nicosiai*. Sex of few individuals was unidentified during this study due to the small body size and they were mostly hatchlings (Table 10).

**Table 10.** Populations structure of chameleons in central Menabe during January to April 2007.

| **Species** | **n** | **Sex (proportion)** | | | **Life stage (proportion)** | | |
|---|---|---|---|---|---|---|---|
| | | **Female** | **Male** | **Unknown** | **Hatchling** | **Juvenile** | **Adult** |
| *B. brygooi* | 491 | 0.62 | 0.36 | 0.02 | 0.08 | 0.03 | 0.89 |
| *F. labordi* | 139 | 0.67 | 0.33 | 0.00 | 0.00 | 0.03 | 0.97 |
| *F. nicosiai* | 86 | 0.36 | 0.51 | 0.13 | 0.42 | 0.14 | 0.44 |
| *F. oustaleti* | 21 | 0.52 | 0.43 | 0.05 | 0.00 | 0.48 | 0.52 |

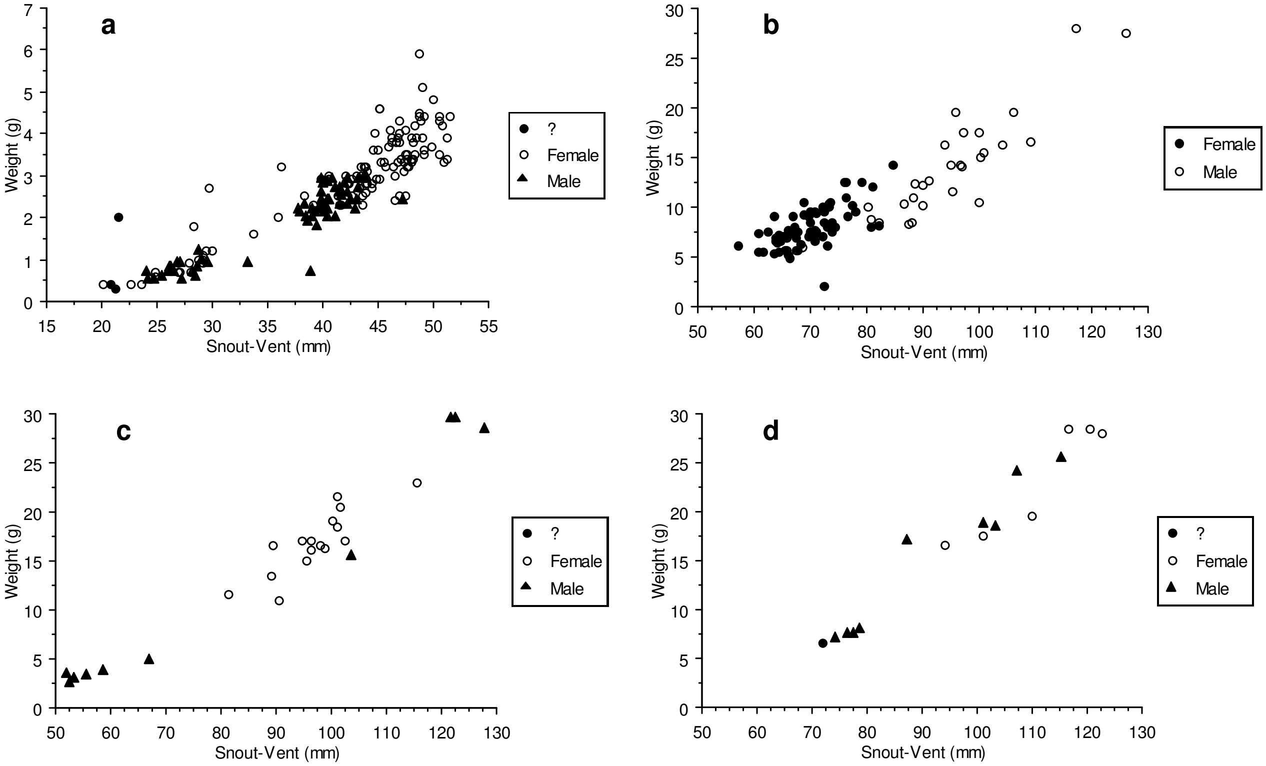

**Figure 5.** Growth index for chameleon community found in central Menabe during January to April 2007. **(a)** *Brookesia brygooi* ; **(b)** *Furcifer labordi* ; **(c)** *F. nicosiai* ; **(d)** *F. oustaleti.*

### *Chameleon diet*

In total, 61 faecal pellets were collected. Remains in fecal pellets were grouped into 14 prey categories (Table 11). Spiders were the most available prey for chameleons within all habitat types. The three chameleon species *B. brygooi*, *F. labordi* and *F. nicosiai* prey mostly on coleopterans, hemipterans, spiders, dipterans, orthopterans, and hymenopterans. *Furcifer labordi* and *B. brygooi* contained the great several of preys. Larvae were found to be an exceptional prey of *B. brygooi*. Two to five percent of *Furcifer labordi* prey were constituted by odonata and Neuropterans but these were not sampled by sweep net method. Phasmopterans were available in the forests but were unused as food by chameleons species encountered in central Menabe during this study.

**Table 11.** Prey types and dietary of three chameleon species and availability of prey in central Menabe. *n* = Total number of samples or chameleons.

| | Percent Frequency In Sweep Samples | Percent Frequency In Diet | | |
|---|---|---|---|---|
| | | ***B. brygooi*** | ***F. labordi*** | ***F. nicosiai*** |
| **Prey category** | n = 30 | n = 10 | n = 41 | n = 11 |
| Araneae | 77 | 50 | 51 | 40 |
| Blattoptera | 20 | 20 | 7 | 0 |
| Coleoptera | 53 | 80 | 88 | 100 |
| Diptera | 20 | 20 | 21 | 20 |
| Hemiptera | 20 | 40 | 56 | 70 |
| Hymenoptera | 17 | 10 | 36 | 10 |
| Lepidoptera | 10 | 10 | 7 | 10 |
| Mantoptera | 3 | 0 | 7 | 0 |
| Neuroptera | 0 | 0 | 2 | 0 |
| Odonata | 0 | 0 | 5 | 0 |
| Orthoptera | 13 | 10 | 19 | 30 |
| Phasmoptera | 17 | 0 | 0 | 0 |
| Larvae | 0 | 10 | 0 | 0 |
| Unidentified | 0 | 40 | 24 | 20 |

## DISCUSSION AND RECOMMENDATIONS

Our results from central Menabe revealed that the distribution and density of chameleon assemblages varies between sites representing areas of diverse vegetation structure. Tsitakabasia, Kiboy, Kirindy CFPF and Ampataka forests had the most chameleon species. Otherwise, species richness of chameleons in central Menabe was lower than that of Tsingy de Bemaraha National Park to the north which contains seven species (Randrianantoandro *et al*., 2007) and was higher than that of Mikea Forest (3 species) to the south (Raselimanana, 2004). No species of *Brookesia* minima-group was found during this study or previous studies in central Menabe (Bloxam, 1996, Glos and Volahy, 2004).

Previous work in the rainforests of Madagascar compared the use of disturbed and riparian forests by chameleons (Jenkins *et al*., 2003). Results showed that chameleon abundance was highest in the low-disturbance and riparian forest. Similarly, research undertaken in the western deciduous dry forests of Tsingy de Bemaraha National Park confirmed that habitat disturbance is a major threat to certain *Brookesia* and *Furcifer* species (Randrianantoandro J. C., unpublished data). Brown (2001) mentioned that the reptile density values recorded were low in disturbed sites. The main outcome of our study in Menabe was that all chameleon species that occur in central Menabe were affected by habitat disturbance. Most vulnerable species were *F. nicosiai* and *F. labordi* which occurred in low densities in the highly disturbed areas. Furthermore, *F. nicosiai* was less abundant than *F. labordi* in central Menabe. Jesu *et al.* (1999) revealed that *F. nicosiai* is extremely vulnerable to habitat modification in the Tsingy de Bemaraha National Park. The northern central Menabe was considered an important sites for this species and also *B. brygooi*. *Furcifer labordi* was found at highest density in low-disturbance forests of Bedo baobab and Kirindy CFPF. Glos and Volahy (2004) however recorded few individuals of *F. labordi* in the Bedo baobab forest. The reason is probably that we observed that perch height of this taxon was highest in this area than in the other sites during this study. Due to these characters, chameleons are good indicators of habitat change. Long term population studies have not been reported for any Malagasy chameleon species except *B. perarmata* in the Tsingy de Bemaraha National Park.

### *Chameleon monitoring*

Distance sampling (Buckland *et al.* 1993) is well suited for the spatial and temporal comparison of chameleon densities. This method was adopted for chameleon studies in the rainforests of Madagascar (Brady *et al.* 1996; Jenkins *et al*., 1999; Brady and Griffiths, 1999; Jenkins *et al*., 2003). Brady & Griffiths (1999, 2003) and Jenkins *et al.* (2003) have recommended distance sampling method for monitoring chameleons. It was recently used in Madagascar (Andreone *et al*., 2005; Randrianantoandro J. C. unpublished data) and in South-Africa (Reisinger *et al*., 2006). Surveying chameleons using distance sampling was suitable for a short research project and provides good results when the encounter rates are high. Otherwise, the species can be pooled within detection groups and overall densities can be calculated for each group (e.g. *Brookesia* and *Calumma* in Brady *et al*., 1996; Jenkins *et al*., 1999).

Glos and Volahy (2004) revealed that chameleon abundance was higher than for other reptiles and *F. nicosiai* was the most frequently encountered species in central Menabe. The calculated density of *F. nicosiai* was higher in central Menabe than in its terra typica (Tsingy de Bemaraha National Park) (Randrianantoandro J. C., unpublished data).

For monitoring by using the distance sampling method, we suggests that transect line of 1 x 1 km that is used by the DWCT team is appropriate to the habitat structure within central Menabe but that surveys should focus on chameleons. Furthermore, the number of two surveyors along the transect line responds to the one of the four assumptions required by distance sampling to detect all animal at zero distance from transects line (Buckland *et al*., 1993).

Brady and Griffiths (1999) announced guidance for chameleon monitoring programmes. All are found to be suitable for our chameleon study in dry western forests as central Menabe during this study.

We advise the following protocol for the future chameleon monitoring:

1. surveyor training;
2. utilization of head lamp type “Petzl Myo xp” was very efficient for searching chameleons;
3. transects should cover the elevation gradient within the site;
4. transect lines of 50 x 3 m are installed randomly as its direction, 24 hours before its survey across different stratum;
5. a buffer zone of 5-8 m between trail and transect lines are occupied;
6. transect lines should be set properly: same direction from the beginning to the end, follow the land contours on 1 m above the forest floor;
7. a minimum of two surveyors are required for a survey alongside the transect lines;
8. a vertical detection ceiling of 6 m in rainforest (Brady and Griffiths, 1999; Jenkins *et al*., 2003; Andreone *et al*., 2005) and 7 m in dry forest should be established;
9. to avoid the high coefficient of variation (error) by calculating the densities, a minimum of 30 observations of each species is required;
10. series of perpendicular distance are truncated from 3 to 6 m depending on body sizes of chameleons species or group, and habitat structure for distance sampling analysis.

### *Habitat preference of chameleons*

Chameleons were found mostly along the forest than path transects in central Menabe. However, paths are non-randomly distributed and are not representative of the forest as a whole (Jenkins *et al.*, 1999). Used trails have different habitat structure from the forest interior, typically possessing a dense layer of ground vegetation (Brady *et al.*, 1996). This could have important ramifications for *Brookesia* spp., which may be largely restricted to this ground layer (Glaw and Vences, 1994).

Human activities and habitat types affected the distribution and abundance of each species. One of the most important points revealed from this study was the rarity of *B. brygooi*, *F. labordi* and *F. nicosiai* in high-disturbance forest. Our results show that these species depend on the primary structure of the forest. *Furcifer labordi* was one of the eight vulnerable species which are restricted to primary habitats (Raxworthy, 2003). This species was most abundant in two forests which have a different structure: Bedo forest is rather open and the trees are baobab large and in Kirindy CFPF the forest is relatively intact but there are permanent trails for selective logging and ecotourism. The high abundance of *F. labordi* at these sites is probably primarily due to its elevation but these forests have large gaps and trails that clearly provide suitable roosting and foraging habitat.

The dwarf chameleon *Brookesia brygooi* was encountered mostly across the forest transect where vegetation 0-1 m above the forest floor and understorey cover were high. Abundance of this species was found to be highest when understorey disturbance was low. Raxworthy (1991) revealed that *Brookesia* roosting perches were normally between about 0.30-1 m above the forest floor, in low shrub vegetation. However, during this study and research undertaken in Tsingy de Bemaraha National Park, we observed some adult males roosting height at 2.4 m and occasionally at 4.5 m in central Menabe.

Some *Furcifer* species may prefer the open and generally more disturbed habitat characteristic of trails. The disturbance along the trail can increase the insects' richness and invasion of opportunistic species (Begon *et al.* 1990). Trails may therefore provide distinct feeding opportunities for sit and wait predators like chameleons. In Kirindy CFPF forest, the abundance of *F. labordi* alongside the CONOCO path during the night was possibly to avoid nocturnal predation by snakes or lemurs. *Furcifer labordi* was also found abundantly in the forest interior of Bedo baobab forests due probably to different factors such as the intact structure of the forest habitat, availability of prey, and elevation. Forest chameleons tend to occur in places where insects swarm (Raselimanana and Rakotomalala, 2003). Rainfall and hydrology also influence the seasonal permanence of wetlands, which in turn affects their productivity and ability to support certain invertebrate taxa (Anderson and Vondracek, 1999). Chameleons are arboreal species and with their elongated tongue which may extend up to at least two times the body length, they can catch insects over long distances (Glaw and Vences, 1994; Raxworthy, 1991). Due to this mechanism, preys are constituted principally by invertebrates (Garcia and Vences, 2002). Our results show that the three chameleon species (*B. brygooi*, *F. labordi*, and *F. nicosiai*) in central Menabe feed mostly on arthropods, mostly coleopterans, hemipterans, spiders, dipterans, orthopterans, and hymenopterans. We found a large similarity between preys of these Malagasy chameleon and the three chameleon species in Cameroon. Hofer *et al.* (2003) mentioned that *Chamaeleo montium*, *C. pfefferi*, and *C. quadricornis* prey almost entirely on arthropods, mostly, coleopterans, heteropterans, hymenopterans, dipterans, and spiders. Otherwise, Raxworthy (1991) reported that prey of chameleons is largely made up of invertebrates, particularly dipterans and orthopterans. However, Garcia and Vences (2002) reported that small mammals and birds were noted as potential prey for some larger species. *Calumma parsonii* was reported to consume small birds and lizards such as *Phelsuma* (Le Berre, 1995; Risley, 1997; Abate, 1998).

Diet of *F. oustaleti*, the largest chameleon species in Madagascar (Brygoo, 1971), was not provided in this study. This species may be feed on large prey. In the Forest station of Ampijoroa, one adult male of *F. oustaleti* had a dead bird (probably an adult of *Foudia madagascariensis*) in its mouth (Garcia and Vences, 2002). *Furcifer oustaleti* occurs in open areas with bushes or tree savanna or at the forest edge (Raselimanana and Rakotomalala, 2003) with *F. lateralis* which was found outside the transects by Glos and Volahy (2004). These two species were less or not recorded during this study across the forest and trail transects.

Raxworthy (2003) mentioned that the distribution and abundance of reptiles and amphibians were also affected by the elevation which has produced a broad diversity of habitats. Forest structure and composition of tree species varied remarkably in relation with the topography and soil characteristics (Abraham *et al.*, 1996; Rakotonirina, 1996). Therefore, chameleon assemblage and densities varied between sites in central Menabe. Sites situated in the west are characterized by the low altitude and is associated with a high abundance of Baobab trees. *Adansonia* spp. seem to offer important resources to a wide range of animals and were largely depending on hawkmoths for pollination. Moreover, baobabs are an essential nectar resource for many other insects and are attacked by a variety of insect pests, including hemipterans and lepidoptera larvae (Baum, 1996). Some animals and particularly insects exploit the flowers destructively (Du Puy, 1996). Therefore, *F. labordi* were abundant in Bedo baobab forest. This forest type represented a low density of *B. brygooi* due probably to the habitat structure (e.g. low understorey cover, low vegetation 0-1 m above the forest floor and low litter depth). Furthermore, rainfall decreases from west to east in central Menabe. This gradient is noticeable even on the small scale of a few kilometers within the CFPF forestry concession (Rakotonirina, 1985). We believe that climate and soil characteristics affected remarkably the vegetation structure in Bedo baobab forest and consequently affected the distribution of chameleon assemblage. In comparison to the other protected area, *B. brygooi* was more abundant in the Tsingy de Bemaraha National Park representing a high altitudinal gradient than in central Menabe (Randrianantoandro J. C., unpublished data). The presence and abundance of this species in the forests between the Manambolo and Tsiribihina Rivers is unknown. In 2006, research undertaken in the south of Manambolo did not reveal the presence of this species (Randrianantoandro J. C., unpublished Data).

Two new species were recorded in this study that were not detected in previous surveys (Bloxam *et al.*, 1996, Glos and Volahy, 2004): *Mabuya tandrefana* and *Paroedura vahiny* (Nussbaum and Raxworthy, 2000; Nussbaum *et al.* 1999), the latter species was only previously known from Dabara forest and near Manja, both in the south.

### ***Conservation***

Malagasy chameleons are subject to a large international market associated with the pet trade (Raselimanana and Rakotomalala, 2003). Since 1996 the trade of several species of chameleons (*Furcifer* and *Calumma*) has been banned under CITES regulations. *F. lateralis*, *F. oustaleti*, *F. pardalis* and *F. verrucosus* are the only chameleon species not affected by these export restrictions (CITES Secretariat 1995). *Brookesia* was not part of this embargo. Except *B. perarmata*, all Malagasy chameleon species are listed in the CITES appendix II.

Only four chameleon species: *B. perarmata*, *F. minor*, *F. campani*, and *F. labordi* are listed Vulnerable in the IUCN Red Data Book (1996). The important pressure that threatens the continued existence of several chameleons is the loss of natural habitat associated with human activities. Extensive habitat loss and fragmentation within each geographic domain have probably led to significant declines in overall population levels

(Brady *et al.*, 1999). However, the lack of information in some areas makes it difficult to assess the conservation status of some species (Raselimanana and Rakotomalala, 2003).

This study suggests that *F. nicosiai* should be categorized as Vulnerable based on IUCN criteria (IUCN, 2001) B1ab (iii, iv); i.e. the extent of occurrence is < 20,000 km$^2$ and highly fragmented. *Furcifer nicosiai* has severely fragmented populations. This species was recorded in Tsingy de Bemaraha National Park (Terra Typica) and Tsimembo forest (Rakotondravony H. A., person. com.), central Menabe, Andranomena Special Reserve, and has been reported to occur in Belitsaka forest in the North of Tsingy de Bemaraha Natural Reserve (Randrianavelona, unpublished data). These five locations are isolated from each other by significant physical barriers (such as rivers and non-forest vegetation). Furthermore, there is continuing decline in the extent and quality of its habitat. The forests outside protected area (Belitsaka and Tsimembo forests) or within the conservation site on southern central Menabe, and north of Tsingy de Bemaraha National Park are under heavy pressure. Illegal collection of this species for pet trade was also observed within the limits of the Strict Nature Reserve N°9 (Jesu *et al.* 1999).

Dry deciduous forests (3,987,000 ha = 3,987 km$^2$, of which 24 % is degraded/secondary forests) are scattered in the western part of Madagascar and near to coast between the Manambolo and Onilahy rivers (Dufils, 2003). A large component of these forests is made of habitat that is not suitable to *Furcifer* species. The transitional and deciduous forests of the west and less extreme southwest contain five endemic species of dwarf chameleons: *B. bonsi, B. brygooi, B. decaryi, B. exarmata, and B. perarmata.* In addition to *F. nicosiai* and *F. labordi*, some *Furcifer* species are also endemic to the tropical dry forest of the west and southwest such as *F. angeli, F. antimena, F. belalandaensis*, *F. monoceras*, *F. rhinoceratus*, and *F. tuzetae*. Except *F. angeli*, geographic distributions of these species within protected areas were unknown (Raselimanana and Rakotomalala, 2003). Most of *Furcifer* species (80 % of the 18 species) have yet to be evaluated by the IUCN and of the taxa found in the west two are possibly extinct (*F. belalandaensis* and *F. tuzetae*). Raxworthy (2003) revealed that *F. belalandaensis* has a high extinction risk (Raxworthy, 2003). Research on distribution, habitat preference, and the IUCN Red List assessment of these chameleon species are recommended to preserve the wildlife populations.

The new protected area constituted by the one of largest remaining block of western dry deciduous forests in Madagascar. Menabe was identified as a site important for biodiversity presentation (Randrianandianina *et al.*, 2003). Faunal research in this area has concentrated on vertebrates, particularly the mammals. To our knowledge, there was no extensive chameleon survey in central Menabe Region. The conservation of this area is needed to maintain the viable populations of endangered species that's occurred in this area such as the Giant Jumping Rat *Hypogeomys antimena*, one of the flagship species of central Menabe and the flat-tailed tortoise *Pyxis planicauda*. Their distribution areas are restricted and limited in the north by the Tsiribihina River. Furthermore, the Kirindy CFPF forest is a popular site for those hoping to see a *Cryptoprocta*. Its long-term population decline appears inevitable (Hawkins, 2003).

The method used by DWCT for monitoring species such as *Hypogeomys antimena, Pyxis planicauda,* and *Mungotictis decemlineata* in central Menabe offered an important baseline to know how populations distribution, abundance, and habitats evolve spatially and temporally. Otherwise, chameleons can be easily detected at night. Furthermore, chameleon has an importance to ecotourism in Menabe. All tourists who visit Kirindy CFPF forest require seeing chameleons (Randriamiarisoa, person. comm.). *Furcifer labordi* was identified as one of the several species very attractive to tourists and therefore might be interesting to be included into conservation management (Glos and Volahy, 2004).

In Bedo baobab forest, an important population of *Pyxis planicauda* was observed during this study. An estimate of the population density of this species was probably a weakness by using distance sampling because this tortoise is partially a ground-dwelling species (Sambiravo, personn. comm.). The high level of ongoing deforestation in the Menabe region is likely having a strong effect on this species. Baobab forest is ecologically unique and, thus, their conservation is a great importance. In this forest, the baobabs constitute keystone mutualists. This means that were baobabs to go extinct in a dry deciduous forest, one would expect a cascade of extinction encompassing both animals (the mobile links) and other plants (Du Puy, 1996). Bedo Lake has been designated as a RAMSAR site in 2007. It is surrounded by the baobab forests. Therefore, the transformation of some of the remaining natural habitat of the region, such as forest fragments of Bedo into the protected areas is a necessary step for the long-term conservation of the most vulnerable species occurring in central Menabe and its habitat.

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