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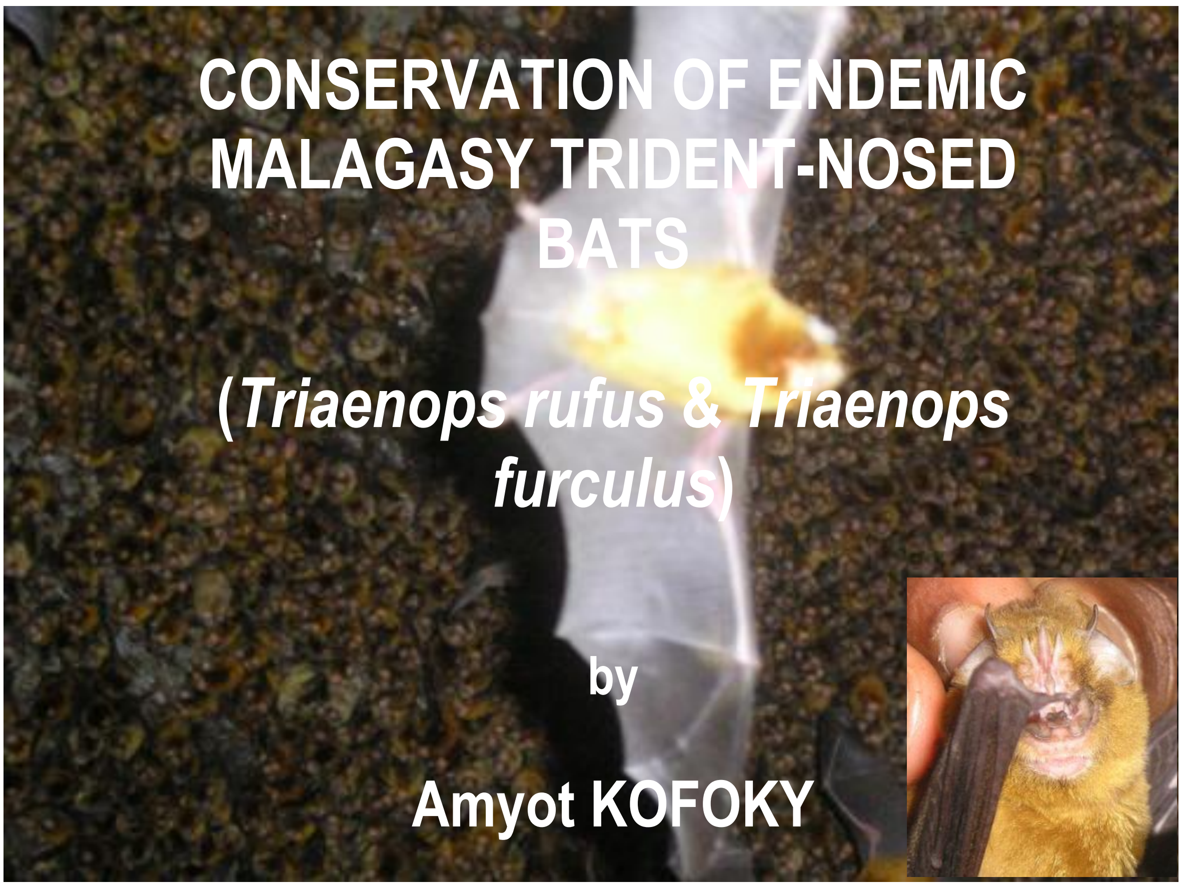

CONSERVATION OF ENDEMIC MALAGASY TRIDENT-NOSED BATS

(*Triaenops rufus & Triaenops furculus*)

by

Amyot KOFOKY

C/O Ecology Training Program
WWF Madagascar
BP 738
Antananarivo (101), Madagascar
Phone: +261 32 02 013 54
Email: amyot320@yahoo.fr

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Conservation of endemic Malagasy Trident-nosed Bats (*Triaenops rufus* & *Triaenops furculus*)

RUFFORD SECOND GRANT FINAL REPORT

AMYOT F. KOFOKY

C/O Ecology Training Program , WWF Madagascar[1]
BP 738
Antananarivo (101), Madagascar

PART ONE

SUMMARY

Until very recently, Malagasy bats received notably less attention from scientists and conservation biologists than other groups of mammals. In this study, I investigated the roosting ecology (roosts and foraging area) and conservation of the two sympatric *Triaenops* trident-nosed bats in western and southern Madagascar's karst belt (Saint Augustin, Bemaraha and Anjohibe). Using mist nets and bat detectors in combination with radio telemetry survey, I assessed the importance of foraging habitats for the species and their association with intact forest. I concluded that both *Triaenops* are cave-dwelling species. However, *Triaenops furculus* was strongly associated with intact forest. *T. rufus* was moderately forest bat. The results from Bemaraha and Saint Augustin indicated the importance of forest habitats for cave-roosting bats

INTRODUCTION

Vertebrate conservation in Madagascar has relied for many years on the results of biological inventories of important sites to determine biodiversity and set management priorities (Raxworthy and Nussbaum, 2000; Brooks *et al.,* 2002; Mittermeier *et al.*, 2004,Ganzhon *et al.*, 2003; Goodman and Benstead, 2005;and Yoder *et al.*, 2005). These studies produced a wealth of new information and the description of many new vertebrate species to science and the data collected are now being used to plan Madagascar's new suite of protected areas. Remarkably however, given the well established contribution that bats make to mammalian diversity and the efforts of numerous small mammal survey teams (e.g. Raxworthy and Nussbaum, 1994; Ganzhorn *et al.*, 2003), the bats of Madagascar were rarely included in sample protocols. This resulted in a lack of capacity by Malagasy people to study bats and a large gap in knowledge (Peterson *et al.*, 1995). A series of capacity building projects run by the

[1] Present address

University of Aberdeen and the Ecology Training Programm WWF Madagascar since 1999 to overcome the years of neglect trained many students and launched the careers of a number of Malagasy bat biologists and their studies are now coming to fruition. It is only in the last five years that bats have regularly featured in research, inventories and conservation plans (e.g. MacKinnon *et al.*, 2003; Goodman *et al.*, 2005c)..

In my first Rufford grant I investigated the roosting ecology and conservation of cave bats in the karst of western Madagascar. During this period I became particularly interested in the species that only roost in caves, such as the *Triaenops* trident-nosed bats. Some of the results from this work are now published and give direction to new areas of study. In April 2005 I attended the Global Mammal Assessment Workshop run by the IUCN in Antananarivo and along with colleagues from other institutions we determined the Red List status of all Malagasy bat species. It came as a surprise to me that *Triaenops furculus*, which has previously been listed as 'vulnerable' was judged to be 'least concern'. This new assessment reflected the opinion that *Triaenops* bats are not dependent on forest. With my knowledge of the implications of bat echolocation and body shape I suspected that this might be incorrect and I am therefore seeking to focus this study on these bats.

My objective was therefore to assess the use of forest habitats by the endemic *T. rufus* and *T. furculus* in western Madagascar.

STUDY SPECIES

In Madagascar, the family of Old World leaf nosed bats, Hipposideridae is represented by 4 species which three endemic (Simmons 2005). In this study, we particularly aim to assess the conservation status and forest dependency of two species of Malagasy trident-nosed bats (*Triaenops rufus* and *T. furculus.*). Only *T rufus* is endemic and both species are known roost in caves, but little is known about their ecology, their habitat requirements. *Triaenops furculus* (IUCN 2001 vulnerable) is known to occur the western and southern part of Madagascar and also Seychelles. While *T rufus* (IUCN 2001 DD) is common in Madagascar. This difference may explain the habitat requirements for the two species.

STUDY SITES

My choice of study sites was there based mainly on the presence of *Triaenops* spp and access to its roosting sites. I chose three sites, Parc National Tsingy de Bemaraha (TBNP), Saint Augustin (SAUG) and Anjohibe (ANJO) (Figure 1), which are all situated in western and southern Madagascar's karst belt and have caves and both *T. rufus* and *T. furculus*.

The first site is Tsingy de Bemaraha National Park, situated in the middle west of Madagascar (Mahajanga Province, Antsalova Sous-prefecture and Bekopaka Commune), between 18°12'S and 19°07'S; and between 44°34'E and 44°56'E. It represents one of the largest landscapes karstic in Madagascar. The area was gazetted as a World Heritage Site in 1991 and as a National Park in August 1998. The ecosystems of the TBNP range from grassland to tropical deciduous dry forest on limestone karstic landscape (ANGAP, 2003). This site was visited during October and November 2005.

The second site in the Toliara Region was a series of caves near Saint Augustin in the south (23°33'14. 4''S and 43° 45' 42. 0''E). The sites are characterised by the disturbed spiny forest on limestone karst and gallery forest on sand. There are agricultural fields and a few scattered villages. This site was visited during April and June/July 2006.

Anjohibe formed the third site surveyed and located between 15°30’ S to 15°34’ S and 046°50’ E to 046°55’ E. It is also characterized by deciduous dry forest on limestone karstic. This site was visited during August 2006.

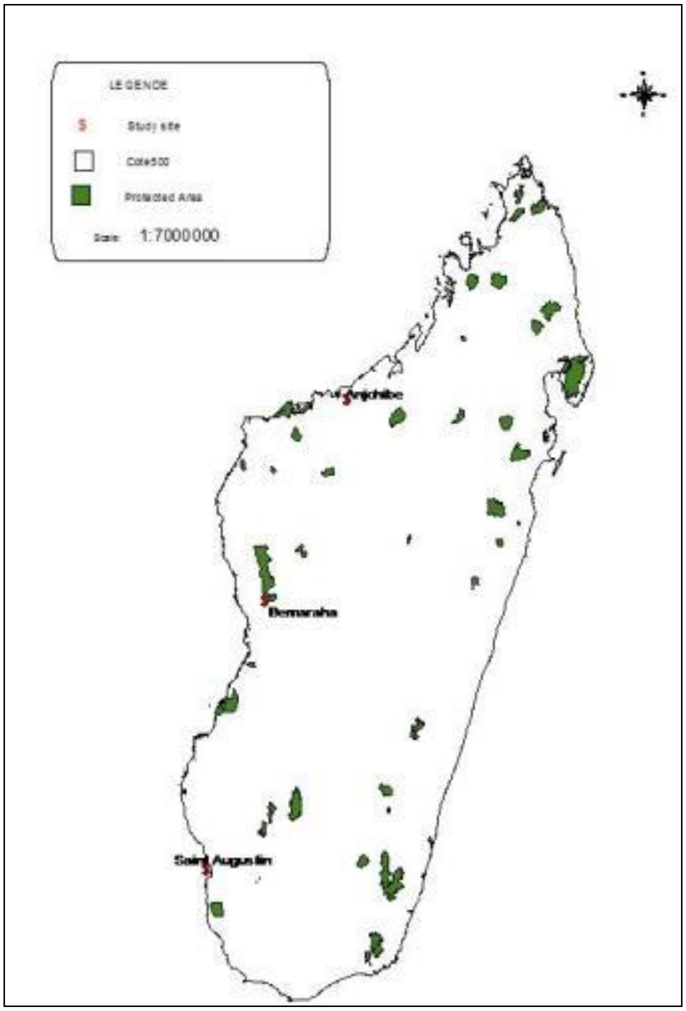

Figure 1 : Study sites location

METHODS

As outlined in my proposal, I used acoustic determination of flying bats and radio tracking to assess habitat use in these species. I also used mist netting to catch bats for radio tagging and to assess activity in different habitats.

Mist netting

Mist nets were used to trap flying bats between dusk and 22h00. Nets were usually placed in locations deemed to be suitable for trapping bats and these were trails, gaps, rivers and edges. One trap site was conducted each night and usually consisted of 37-42 m of netting. Nets were regularly monitored and the bats were extracted soon after capture. The sampling protocol consisted of trap sites inside the forest, at the forest edge and in non-forest habitats at varying distances away from the forest.

As wing morphology of bats can be used to predict flight, hunting behaviour and species' ecology (Norberg and Rayner, 1987), the extended right wing of each captured bat was traced, for measurements of wingspan (B) and wing area (S) (Saunders and Barclay, 1992) by extending the tail and right wing. These tracings were repeated three times and the average was used in statistical analysis (Jacobs, 1999). These measurements were used to derive three further parameters: wing loading (WL), aspect ratio (AR), and wingtip shape index (I) (Norberg and Rayner, 1987).

The WL, a measure of the surface area of the wing compared to the body size, is considered to be positively correlated with minimum speed and negatively correlated with manoeuvrability (ability to turn tightly) and agility (ability to turn quickly) (Norberg et Rayner, 1987)

$$WL = \frac{mg}{S}$$

Where m is body mass, g the acceleration due to gravity and S is wing area.
The AR describes the shape of the wings, and it is positively correlated with flight efficiency. High AR values correspond with long narrow wings and energy-efficient flight, low AR values with shorter wings and less efficient flight (Norberg et Rayner, 1987).

$$AR = \frac{B^2}{S}$$

The wingtip shape index (I) indicates the relative shape of the wing tip, high values indicating a pointed wing and low values a rounded wing.

These characteristics have been used to predict flight style and flight ability of bats (Norberg and Rayner, 1987). For this study, we aim to describe the wing morphology of *Triaenops* spp and to predict their flight behaviours in relationship to their foraging ecology

Acoustic sampling

Following the general protocol of inside, near to and far away from the forest, a series of point counts were conducted each night. A Pettersson D240x bat detector was used to sample flying bats in time-expansion and the echolocations were recorded directly onto mini-disks. Each point count lasted 15 minutes and was approximately 200-400 m apart. Call sequences were downloaded into a PC and converted to sonograms to identify species. The recordings were analysed with the software BatSoundPro (Pettersson Elektronic AB, Uppsala) at a sampling rate of 44.1 kHz, with 16 bits/sample, and a 512 pt FFT with a Hanning window for analysis (Russ *et al.*, 2001). Identification of the focal-taxa in this study is straightforward as they have distinctive shapes and frequencies (Russ *et al.*, 2001, Kofoky *et al.*, in prep). Additional recordings were made at some point counts simultaneously using broadband methods (heterodyne or frequency division) to sample the activity of the bats as either 'bat passes' or 'feeding buzzes'.

Radio tracking

Triaenops furculus were radio-tagged during April and July 2006. Bats were caught at Tanambao cave entrances. The aim was to keep a sample of 4 bats with transmitters on each session.

Captured bats were fitted with 0.37g transmitters (LB-2N, 12 days life with aerial length 140 mm, Holohil Systems). We followed Aldridge and Brigham (1988) as transmitters less than 5% of body mass for adult bats were used. Transmitters were attached to the back between the scapulae using latex-based contact adhesive glue (Skin bond).

Bats were released close the cave roost and followed shortly to describe their behavior after tagging. Bats were followed using one or two receivers (Triangulation) from the night after the transmitter was attached until the transmitter fell off or the bat was lost. Each night, bats were monitored either continuously through the night from the time of emergence from their day-roosting sites until their return to their roosting site, or timely through the night. Locations of bats were plotted every 15 min.

Data analysis

For each continuous variable, descriptive statistics (mean ± SD and range) are shown. Analysis of Variance (ANOVA) or test of student t-test was used to test for differences between normally distributed variables or log transformed data, whilst Mann-Whitney, Kruskall-wallis and Spearman rank correlation were used for data that did not conform to normality. In all tests, values of $P<0.05$ were considered significant. I used Principal Component Analysis to look for relationships between bats and inter-correlated physio-biological cave features.

We also use the non statistic Minimum Convex Polygon (Mohr, 1947) MCP and statistical Kernel estimator for delimiting the home ranges of these species. A MCP home range is simply a polygon drawn around the outermost data points of a bivariate plot such that the polygon is always convex. It is one of the oldest and simplest HR models. The main disadvantages of the MCP model are that it often includes areas not used by the animal and its area is highly sensitive to sample size. A kernel home range (Worton, 1989) uses a non-parametric statistical procedure to calculate probabilities of an animal being in various locations in two-dimensional space. It does not assume that the location data are normally distributed and adjusts home range boundaries for local variation in frequency of use. The kernel HR is the most sophisticated of the three models and probably the most biologically realistic. The analyses were carried out using StatView for Windows Version 5.0 (SAS Institute Inc.) and ArcView GIS 3.2.

RESULTS

1- NATIONAL PARK OF TSINGY DE BEMARAHA

My study was in TBNP during October and November 2005 and we surveyed bats in the north and south of the park. The main method was to follow a transect from inside the protected forest to the edge and out towards the savanna and grassland habitats. We therefore completed a 10 km in the north and south using mist netting and acoustic sampling.

1.1- Capture

A total of 328 bats from ten species were trapped; *Rousettus madagascariensis* (n = 143), *Hipposideros commersoni* (n = 58), *Triaenops rufus* (n = 50), *Triaenops furculus* (n = 9), *Miniopterus manavi* (n = 52), *Miniopterus gleni* (n = 1), *Myotis goudoti* (n = 13), *Scotophilus robustus* (n = 1) and *Mops leucostigma* (n = 1).

The furthest trap site was 14 km from the forest and all sites inside the forest are classed as zero metres. There was a significant correlation between distance from the forest and the abundance of all microchiropterans (Spearman Rank Correlation *r* = - 0.55, p = 0.02) and more than 30 bats were caught per night in sites up to 2 km from the edge of the protected forest. Species richness of microchiropterans also showed a similar pattern (SRC *r* = - 0.49, p = 0.01). Neither the abundance of *T. rufus* (SRC *r* = - 0.20, ns) or *T. furculus* (SRC *r* = 0.20, ns) was related to forest proximity but in the case of the latter species there was strong evidence, based on a small sample size, of a close association with the protected forest (Figure 2).

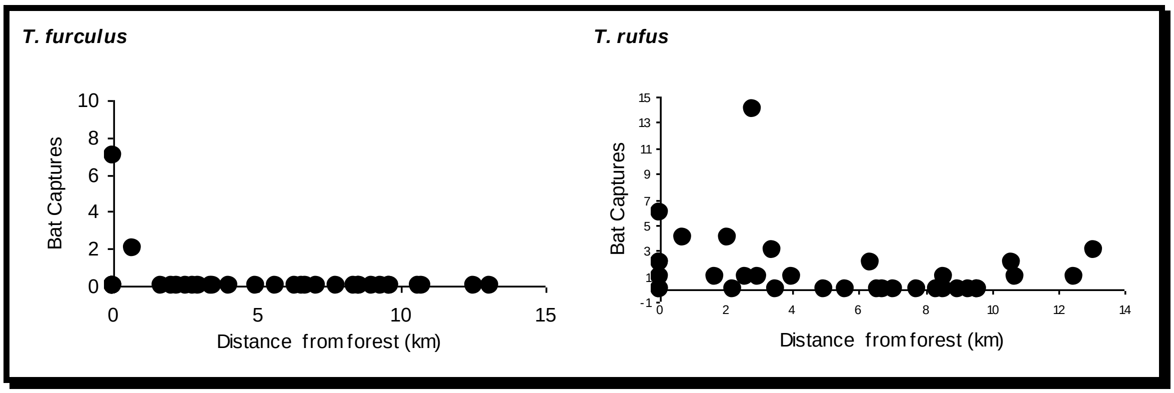

Figure 2: Captures of two *Triaenops* bats at increasing distance from the forest edge (0m)

Analysis of the capture data by habitat type revealed that *T. furculus* was trapped usually in intact forest but that two individuals netted in farmland (Figure 3). *Triaenops rufus* was regularly trapped in forest and farmland but only occasionally in savanna habitats (Figure 3).

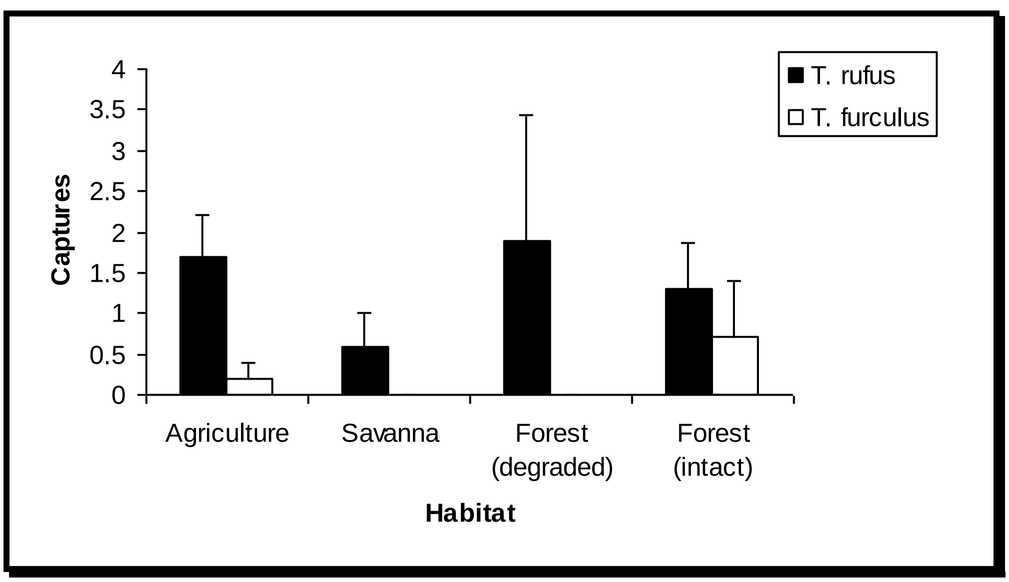

Figure 3: Captures of two *Triaenops* bats in four different habitats

Triaenops furculus was caught at two sites, at the forest edge and 0.7 km from the forest edge. *Triaenops rufus* was trapped a mean distance of 2.9 km ± 1.95 SE from the edge of the protected forest and a maximum of 10.7 km.

1.2- Acoustic sampling

Nine microchiropteran species were determined from recordings of echolocations. Seven of these were also netted during the trapping survey, but *Emballonura* sp. and *Miniopterus majori* were only detected acoustically. Of the 303-point count recordings 192 echolocations were attributed to bat species (Table 1) and a further 176 were from unidentified molossid bats. *Triaenops rufus* was recorded five-times more often that *T. furculus* and was the third most commonly detected species during the survey.

Table 1 : Summary of acoustic sampling results

Species	Number of acoustic determinations
M. manavi	65
M. majori	43
T. rufus	26
H. commersoni	*24*
M. goudoti	15
Emballonura sp.	5
M. gleni	5
T. furculus	5
S. robustus	4

I used the proportion of point counts with each species within 16 distance bands to investigate habitat use and edge effects (Figure 4). *Triaenops rufus* was detected in all but a few distance categories and there was no evidence of any relationship to the forest. By contrast, *T. furculus* appeared to be strongly related to the forest.

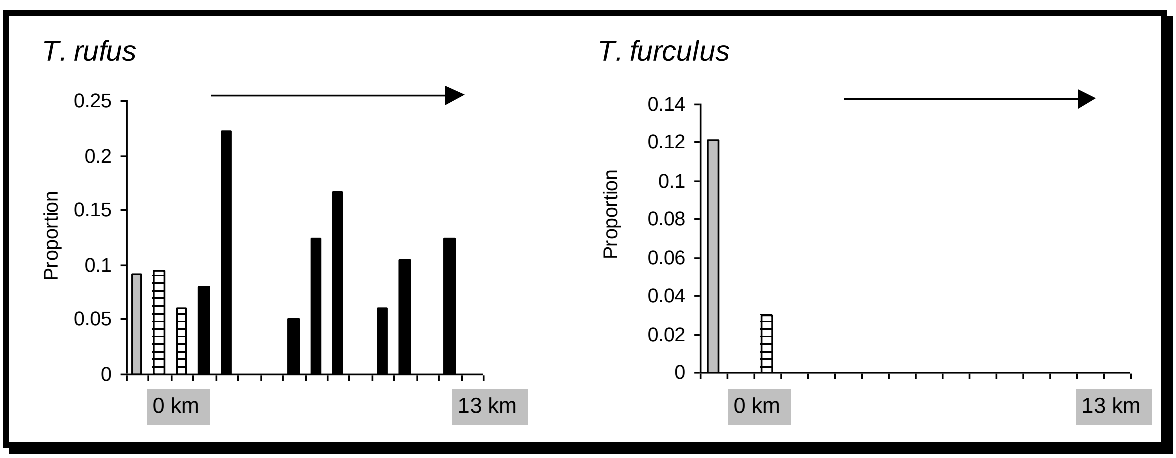

Figure 4: Distance away from the forest (increasing with black arrow) and proportion of point counts with *Triaenops* detections from TBNP. Grey represents forest interior, hatched forest edge and black, the habitats outside of the forest

1.3- Wing morphology

As the bat wing morphology can be used to predict flight, hunting behaviours and species' ecology, three categories of bats can be identified. The species with relatively low aspect ratio and wing loading are classified as high manoeuvrability species. They have relatively short and broad wings allowing them to fly slowly and forage within dense vegetation. On the other hand, those with relatively long, narrow wings (high aspect ratio) and high wing loading are fast flying species generally in open area.

They are classified as low manoeuvrability species. The others species have wing morphology combining a low aspect ratio and high wing loading enable them to fly slowly and manoeuvre within clutter and rapidly in open spaces (Norberg and Rayner, 1987; Jacobs, 1999; Jennings *et al.*, 2004).

In the current study, there were no clear and big differences in the wing morphology of the species of *Triaenops* (Table 2). There is no difference significantly on aspect ratio between the two species (t-test, t=-1.34, p= 0.14). The contrary pattern was observed on the wing loading, there is difference significantly between the species (t-test, t=-3.54, p= 0.0032)
Overall, the values of the aspect ratio and the wing loading of *Triaenops* spp are both low and range respectively from 11.48 - 14.33 (*T. furculus*), 12.44 – 16.21 (*T. rufus*) and 9.95 - 15.58 (*T. furculus*); 11.40 – 19.11 (*T. rufus*). Those species are generally able to forage with high manoeuvrability in clutter habitat.

Table 2 : Wing morphology of *Triaenops* spp

Parameters	Species		t- test	P
	Triaenops rufus (n= 7)	*Triaenops furculus* (n= 9)		
Mass (g)	9.57 ± 0.67	6.65 ± 0.37	-4.01	0.001 (s)
Wingspan B (mm)	0.29 ± 0.006	0.27 ±0.003	-3.11	0.007 (s)
Wing area S (m^2)	0.006 ± 3.503E-4	0.006 ± 1.553E-4	-1.24	0.23 (ns)
Aspect ratio	14.05 ± 0.50	13.20.01 ± 0.28	-1.34	0.14 (ns)
Wing loading ($N\ m^{-2}$)	15.62 ± 1.05	11.60 ± 0.58	-3.54	0.0032 (s)

2- SAINT AUGUSTIN
Contrary in TBNP, *Triaenops spp* in Saint Augustin were assessed and survey from cave roost. Nets were set up across the cave entrances to estimate the population size, population structure (dynamic) of the two species of *Triaenops*. Monitoring with acoustic methods during all night was also undertaken at the cave entrance to assess *Triaenops spp* activities and their behaviour. Acoustic survey with point counts running on 15 minutes an hour at one point was also conducted in various habitats to assess bat activities especially *Triaenops spp* activities. For that, the samples were conducted between 18 to 23 hours. We conducted also a radio-telemetry study for these species to better understanding their foraging area and their estimated home range. We
The study was conducted in two seasons in Saint Augustin (April and July 2006).

2.1- Capture
In total, 4 species *(Miniopterus manavi, M. gleni, Triaenops rufus* and *T. furculus)* were identified and observed in the Tanambao caves. *Triaenops rufus* and *Miniopterus manavi* were the most common species observed. *Miniopterus gleni* was newly recorded and the previous *Otomops madagascareinsis* were not present during the study.
12 hours mist netting at the roost caught and identified 150 bats in April which 22 *T. furculus* and 105 *T. rufus,* and 144 bats in July, which 59 *T. furculus* and 62 *T. rufus*.

The figure below showed the bat activity at the Tanambao cave roost, determined as numbers of bats caught entering or exiting the roost during two all-night mist netting sessions (14-15th May and 15-16th July 2006).
The results showed that *T. rufus* were very active all night at the roost during may 2006. They come in and out the cave any time. Although, *T. furculus* were active only during the six first hours after dusk and three last hours before light. The same evidence was generally observed with *T. rufus* in July, therefore *T. furculus* were active during first 7 hours after dusk. No *T. rufus* were caught during the last hour before light.
In the other hand, in April 2006, *T. rufus* were not spent their time for foraging, although *T. furculus* spent almost the night for their activity within foraging area. The contrary pattern was observed during July 2006, *T. rufus* spent almost their time to foraging area but *T. furculus* used their part time for foraging.

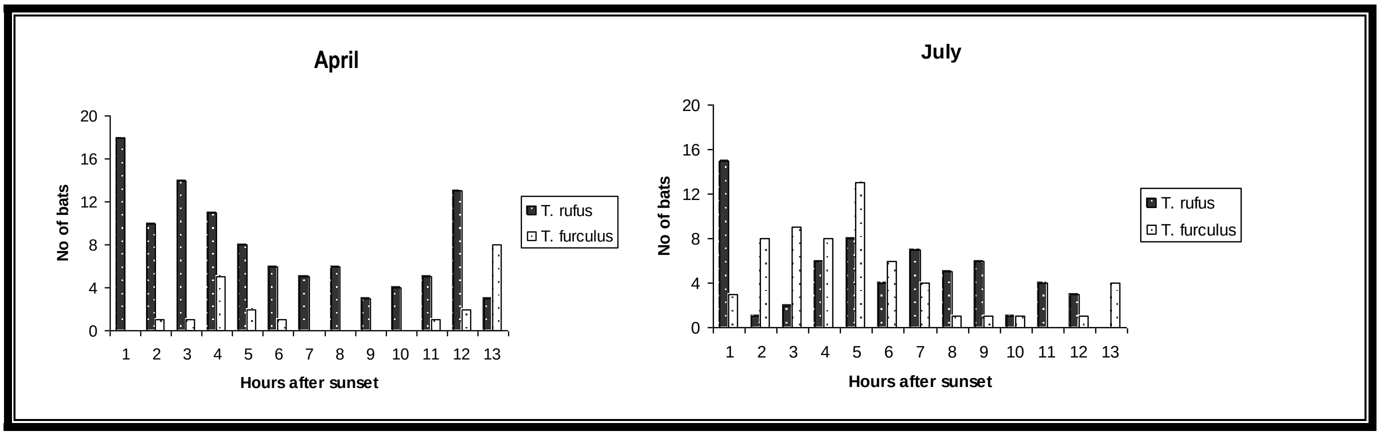

Figure 5 : Summary of 12-hour captures at the roost for *Triaenops rufus* and *T. furculus* in April and July.

2.2- Foraging activity

A total of 294 point counts (PC) were surveyed for bats at four main habitats in Saint Augustin. Overall *Triaenops* activity differed significantly between habitat types (Kruskal Wallis, H= 7.96, p = 0.046; Figure 3). We observed high levels of activity in spiny forest (3.16 activity ± 1.30 SE) and the lowest activities were recorded within agriculture and village (0.190 ± 0.12 SE and 0.194 ± 0.12 SE respectively). Similarly, the duration of bat activity in this habitat was the highest recorded (Kruskal-Wallis, H = 7.95, p=0.046) (4.35s per PC ± 2.01 SE). However, activity was not varied significantly between season (Mann Whitney, U= 9668, p= 0.67, ns) even the graph showed big difference between season. A positive correlation (Spearman rank correlation, Z = 16.85, R = 0.99, p<0.0001) was observed between bat activity and its duration.

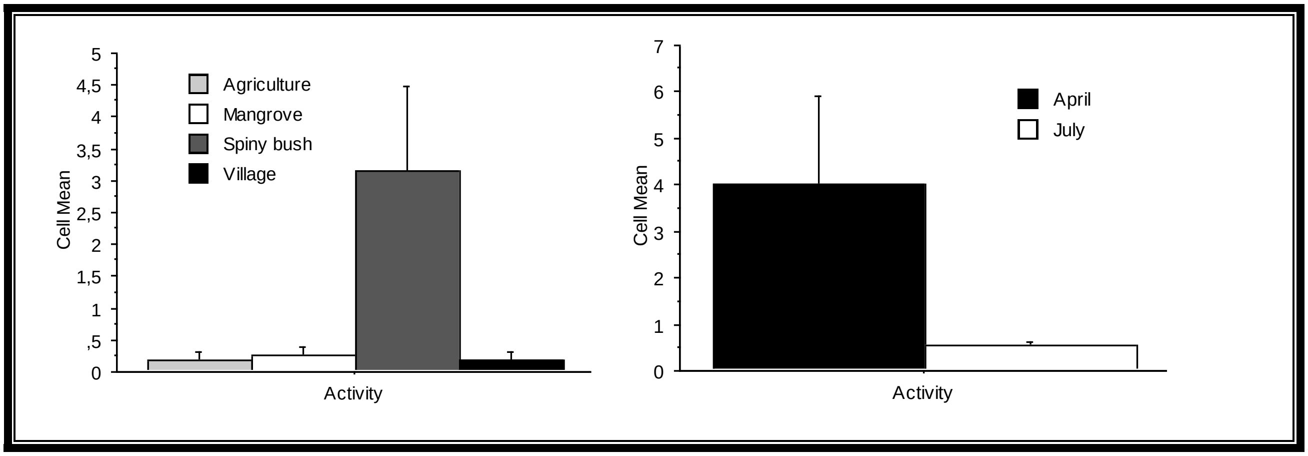

Figure 6: Mean *Triaenops* activity from the main habitats and season

Regarding the sampling time, overall; the activity increased with increasing time. This activity decreased after 23h. The same pattern was observed within spiny bush habitat which the six interval of period have its own activity. However, the *Triaenops* activities between 20-21h were recorded in all habitats. Thus, this period could be a key time for the species activity. The activities between 18-19h were observed only in mangrove and spiny bush. No activity was recorded after 23h except in the spiny bush.

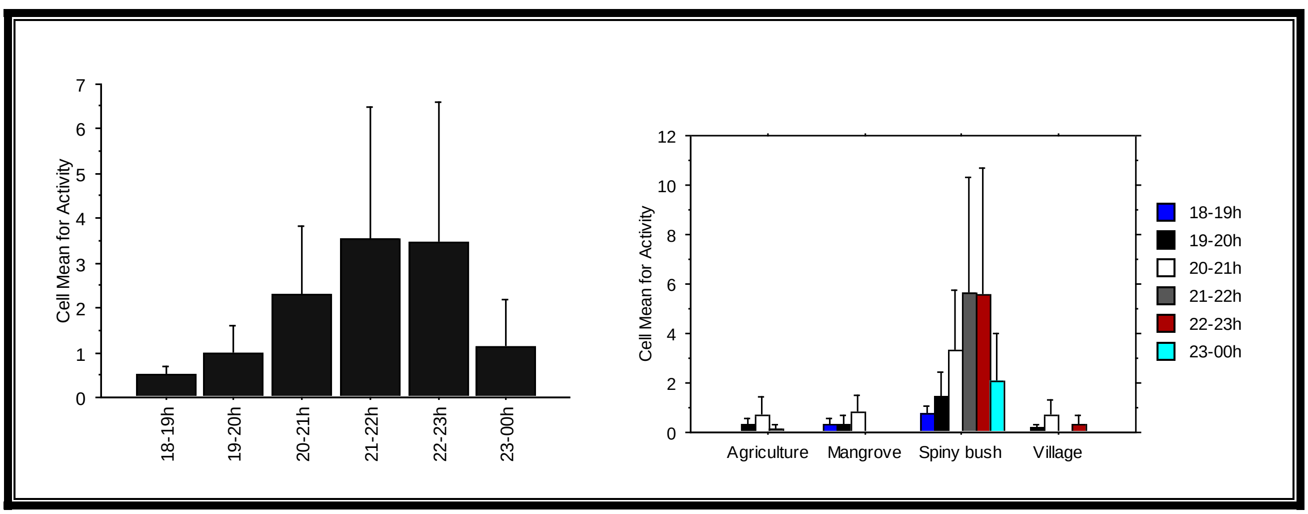

Figure 7: Variation of activity within sampling period and habitat

Overall, 71 calls recorded in frequency division were attempted and analysed. Only 42 calls could be identified into *Triaenops* species which 30 (71.14%) were *T. furculus* and 12 (28.86%) *T. rufus*.

Among the two species assessed with bat detector, the spiny bush had higher number of recorded *Triaenops* calls. We assessed 27 *Triaenops* which 72 % is represented by *Triaenops furculus* (Table 3)

Table 3: Summary of *Triaenops* spp recorded from four main habitats. Values are number of bat observed and frequency of occurrence (%), given in parentheses. n is sample sizes.

: Species	Village (n = 4)	Agriculture (n = 6)	Mangrove (n = 5)	Spiny bush (n = 27)
Triaenops furculus	4 (100)	6 (100)	2 (40)	18 (72)
Triaenops rufus	0 (0)	0 (0)	3 (60)	9 (28)

2.3- Radio telemetry

Seven individuals from 6 *T. furculus* and 1 *T. rufus* were of subject of radio-tracking study. However, *T. rufus* did give any result. Three individuals were tracked in April 2006 and others three in july 2006. The informations of individuals tagged were summarized on the table below.

Table 4: Summary of individuals tagged for radio-telemetry

Bat Code	Species	Sex	Frequency	Marking day	# of observation identified	# of day observation	Cause for end of observation
KARAFY	*T. rufus*	Male	3225	10/04/06	0		Bat disappeared
TOMBO	*T. furculus*	Female	2822	14/04/06	19	10	Transmitter loss
JOBA	*T. furculus*	Female	2223	29/04/06	12	4	Transmitter loss
PAULO	*T. furculus*	Male	1015	03/05/06	9	6	Transmitter loss
BOSCO	*T. furculus*	Male	1036	July 2006	23	4	Unknown
MAHEFA	*T. furculus*	Female	2585	July 2006	45	5	Transmitter loss
YVON	*T. furculus*	Male	3605	July 2006	36	5	Unknown

A Home range (HR) is an area traversed by an individual in its normal activities of foraging, mating, and caring for its young (Burt, 1943). However, many animals tend to move throughout their entire home range each night and always return to a specific area called core area each night. On other hand, the core area is one part of the HR, where the animals spend almost their time for their daily activities (Kaufmann, 1962).

The mean of home ranges of *Triaenops furculus* were respectively 2.41 ± 0.56 ha (MCP) and 8.02 ± 0.75 ha (Kernel). The maximum distance recorded from the roost site was 1681 m (Table 5).
Comparing the two seasons, *Triaenops furculus* have a wide foraging area in July than April 2006.

Table 5 : Home range area estimated with 100% MCP, 95% Kernel and the maximum distance from the roost site

INDIVIDUAL	Saison	MCP (ha) (100 %)	Kernel (ha) (95 %)	Maximum distance from roost
TOMBO	APRIL 2006	4.42	10.41	1486
JOBA		1.92	6.16	670
PAULO		1.41	5.69	678
BOSCO	JULY 2006	3.85	9.45	1681
MAHEFA		2.56	7.89	989
YVON		2.75	8.56	986

However, the activities are concentrating around the roost for Joba and Paulo. Moreover, the three individuals tracked in April have one common area for their activities (Figure 8). All of them used only spiny bush habitat for their daily activity.

Although, the individuals tracked in July 2006 presented very different pattern. They were observed foraging within agriculture habitat (Figure 9).

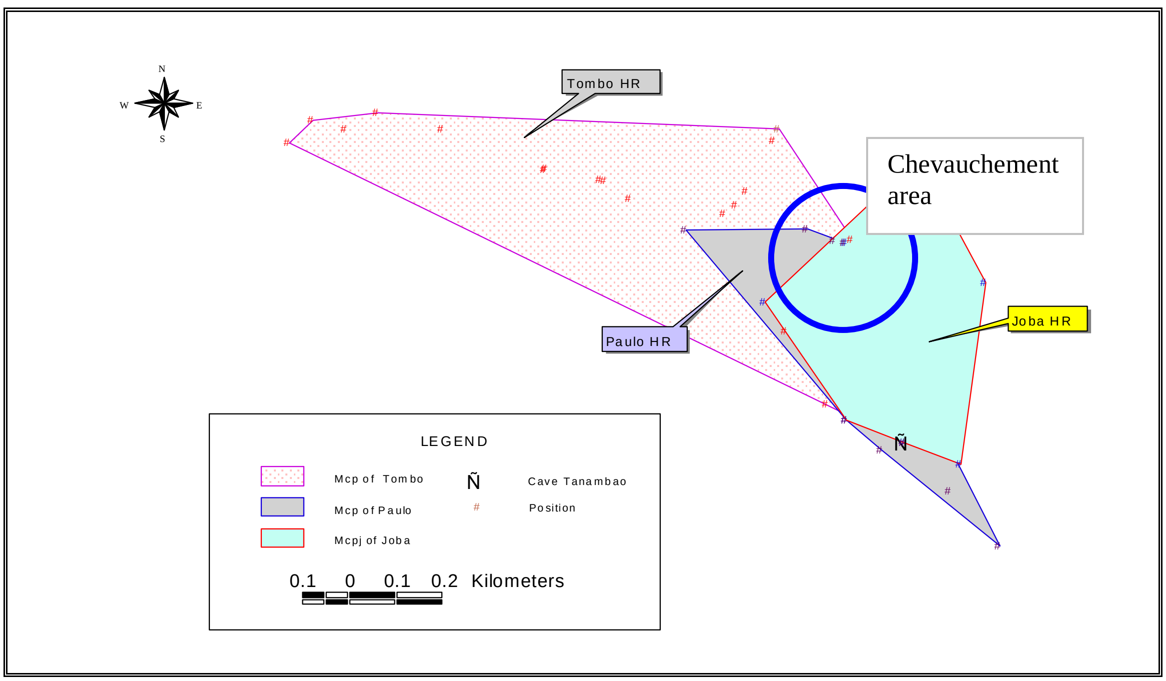

Figure 8: Home range of *Triaenops furculus* in Saint Augustin (April 2006)

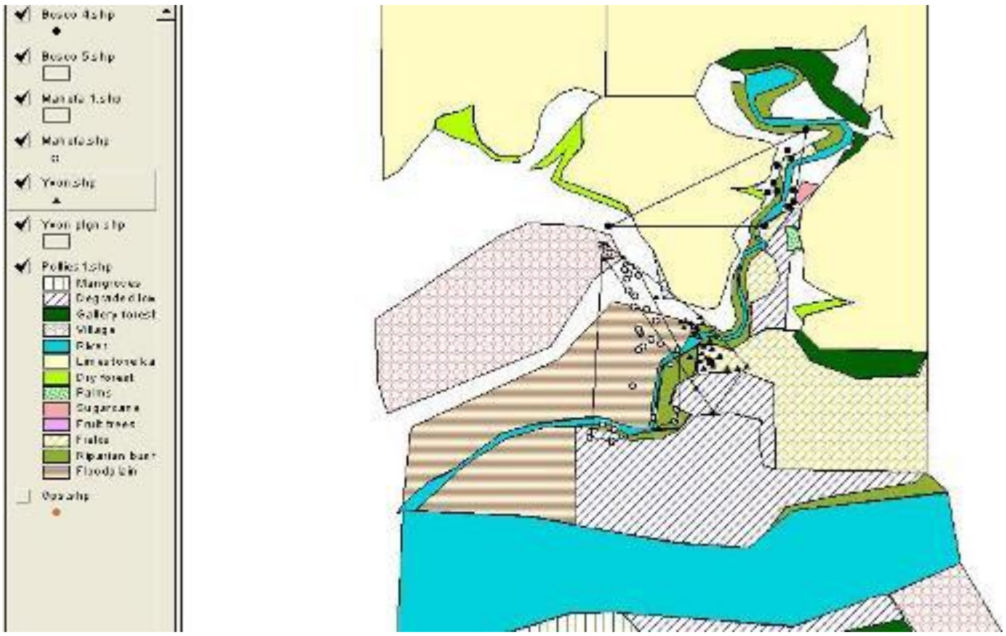

Figure 9: MCP Home range of *Triaenops furculus* in Saint Augustin (July 2006)

3- ANJOHIBE

The mains methods used in Anjohibe were the standard capture using mist net and cave survey. We did not use acoustic survey during this study.

A total of 486 bats from 12 species were caught; *Rousettus madagascariensis* (n = 444), *Triaenops rufus* (n = 2), *Triaenops furculus* (n = 4), *Miniopterus manavi* (n = 7), *Myotis goudoti* (n = 9), *Scotophilus robustus* (n = 1), *S. marovaza* (n = 2) , *Pipistrellus* sp (n =7), *Myzopoda sp* (n = 1) and *Chaerophon leucogaster* (n = 9).

A total of 21 sites were surveyed during the study of bat habitat preference.
The nets were generally set in the clear area and in the path inside the forest. The two species of *Triaenops* (*T. furculus* and *T. rufus*) seemed to have high preference to these habitats as they were trapped mostly.
The cave survey observed 7 species: *Rousettus madagascariensis* (n = 1500), *Triaenops rufus* (n = 600), *Triaenops furculus* (n = 500), *Miniopterus manavi* (n = 303), *Miniopterus gleni* (n = 4), *Hipposideros commersoni* (n = 300), and *Otomops madagascariensis* (n = 7).

DISCUSSION

Until very recently, Malagasy bats received less attention from scientists and conservation biologists than other groups of mammals. However, a recent growth of interest in Malagasy bats, especially microchiropterans, has seen a number of published studies. These consist mainly of taxonomic descriptions and general inventories (Goodman and Cardif, 2004, Goodman *et al*., 2005b, c, 2006), conservation (Goodman, 2006) and their roosting ecology (Ratrimomanarivo and Goodman, 2005c; Kofoky *et al.*, 2006a, b) or their diet (Razakarivony *et al.*, 2005), the current study represented the first attempt to assess the ecology and conservation of the endemic Malagasy Trident-nosed Bats *(Triaenops rufus & Triaenops furculus)* which are considering cave-dwelling species and forest bats.

Bat that forage using echolocation are frequently underrepresented in biological inventories in the tropics and survey are increasingly incorporating the use of ultrasound detectors (e.g. Sedlock, 2001). Acoustic devices have been used for species identification (e.g. Rydell *et al.,* 2002, Jones *et al.,* 2002) and investigations the habitat preference and foraging activity across a range of vegetation types (e.g. Walsh and Harris, 1996; Russ and Montgomery, 2002). In combination of traditional method of capture, data on habitat selection was well described (Kofoky *et al.*, 2006a).

This study showed that capture survey alone can not give an accurate result to predict habitat selection for *Triaenops* species. The use of the capture in combination with acoustic survey and cave survey (direct observation) give an adequate data on bat ecology (Kuenzi and Morrison, 1998; Kofoky *et al.*, 2006a). We never catch *Triaenops* in their foraging area in Saint Augustin. We always heard them with bat detectors. Moreover, in Anjohibe, the trapping data was not sufficient to predict the foraging habitat of the species because we did not use bat detector.
Bats selected areas of forest in Madagascar (both inside and edge). Many authors have reported that bats use these areas preferentially for foraging (e.g., Russ and Montgomery, 2002; Walsh and Harris, 1996). Although, some studies have shown that the edges of forest are selected more strongly than open areas and inside forest (Kofoky *et al.*, 2006a, Walsh and Harris, 1996). This is probably because these habitats harbour higher insect densities (Lewis, 1970). Our result has shown in generally that high activity of *Triaenops* was observed at the nearest forest edges but this activity decreases in increasing the distance from the forest.
Bats used a variety of habitats for both roosting and feeding areas (Kunz, 1982). Foraging areas are influenced by the availability of the roost, food and flight morphology (Kunz and Lumsden, 2003). Brigham *et al.* (1997) reported that small microchiropterans often commute less than several kilometres between roost sites and foraging areas. However, radio telemetry studies indicate that many species of bats forage sometimes at distances from 10 to 30 km from their roost sites (e.g. Barclay, 1989, O'Donnell, 2001). Our result showed the same pattern that *Triaenops rufus* were observed over 10 km from the nearest forest in TBNP. Then, flight morphology have been also used to predict foraging ranges of bats (Norberg and Rayner, 1987), large species and those with high aspect ratios likely to commute greater distances to forage (Jones *et al.,* 1995).
Despite the varying views of the level of importance of relatively intact forest for Malagasy bats (cf. Eger & Mitchell, 2003; Goodman *et al.,* 2005c), the study has tried to collect data for better understanding the level association of Malagasy bats with forest. Overall, it was difficult to classified bats into forest dependent because of their nocturnal habits. Many factors influenced those habitats as the availability of the roost, food, flight morphology, reproductive cycle (Brigham *et al.,* 1997). However, little is known on such dependency in Madagascar. Hutson *et al.* (2001) reported that Malagasy bats are also strongly associated with forest, and the deforestation on the island may threaten bat populations. Although, Goodman *et al.* (2005c) concluded that a considerable percentage of western Malagasy bats are not forest-dependent. Goodman (1999) also reported that all microchiropteran captured in the eastern forest were observed in forest and in the edge. As in TBNP, we don't know if *Triaenops* spp are influenced by the roosts which are the numerous caves or by the presence of the forest. Although, increasing the distance away from the forest and the karst habitat, the abundance of *Triaenops* observed decreased. The study allowed to confirm that *T. furculus* and *T. rufus* were associated with forest. However, only *Triaenops rufus* was also observed in all types of habitats in TBNP. This is probably because either the species doesn't need forest for roosting or they need a minimum of cave roost for their life.

Moreover, *Triaenops furculus* needs also forest for its foraging area. We caught only this species inside forest and at the nearest forest edges in TBNP. Then, the radio-telemetry data showed that the species spent their time foraging inside spiny bush during April 2006. Thus, we can assume that it is strongly associated with forest. However, during July 2006, the same species changed completely its foraging area. It was observed and followed within agriculture area. This is probably because july represents the dry season, *Triaenops* needs to fly greater distance near water source for hunting.
In the other hand; we confirmed that the two species are cave-dwelling species. More than 8 caves were assessed to contain the species (Table 6). However, it was difficult to classify them as forest bats. Either they may need forest for their foraging ecology or they depend mainly on caves roost for their lives. Kofoky (unpublished data) reported that he observed *Triaenops rufus* in Sainte Luce littoral forest which no caves were found.

Therefore, the flight morphology is an important tool to predict foraging ecology of bats. Our results showed that *Triaenops rufus, T. furculus* are clutter bats which can forage inside dense vegetation. The difference between the two species was based on *Triaenops rufus* was more adapted in open area (hight aspect ratio and wing loading than *Triaenops furculus*). By combining the captured and acoustic results, we can suggest that *Triaenops furculus* is forest bat and *Triaenops rufus* is moderately forest bats.

Triaenops furculus was formerly listed as 'IUCN vulnerable' and T. rufus, data deficient, because of habitat loss (Hutson *et al.*,2001), but in the 2005 Global Mammal Assessment workshop in Antananarivo, Madagascar (IUCN, 2005), they were provisionally classed as 'least concern' because of they are more widespread and abundant than previously assumed. However, as we learn, the species were cave-dwelling species and found only in 8 caves in total within Madagascar (Table 6). They are also considering forest bats. So the identification and protection of their roosts should be priorities. In addition, even *Triaenops furculus* is not a common bat and during a survey of 13 forests in western Madagascar, Goodman *et al.* (2005c) only found this species in seven sites. Moreover the species is restricted in the western and southern parts of Madagascar (Ranivo and Goodman, in press). *Triaenops rufus* by contrast was found in 12 sites in western of island (Goodman *et al.* 2005c). Even, *Triaenops rufus* are more common than *T. furculus* (Table 6), they share the same resources (Andrinajoro *et al*; in press). So that, we recommended those species to be classified again as special concern because the major threat should be also habitat loss by deforestation and roost destruction.

Table 6: Summary of distribution of *Triaenops* spp in Madagascar

Locality	**Protected status**	**Cave system**	***T. rufus***	***T. furculus***	**Source**
Sept lacs	NONE	Yes	+	+	LFR data non published, Olsson *et al.*, 2006
Namoroka	PN	Yes	+	+	Kofoky (non published data)
Isalo	PN	No	+	-	Goodman *et al.*, 2005c
Analamera	RS	Yes	+	-	Goodman *et al.*, 2005
Tsimanampetsotsa	PN	Yes	+	+	Goodman *et al.*, 2005c
Ankarana	RS	Yes	+	-	Goodman *et al.*, 2005c
Ankarafantsika	PN	No	+	-	Goodman *et al.*, 2005c
Kirindy CFPF	NONE	No	+	-	Goodman *et al.*, 2005c
Kirindy Mitea	PN	No	+	+	Goodman *et al.*, 2005c
Mikea	NONE	No	+	-	Goodman *et al.*, 2005c
TNBP	PN	Yes	+	-	Current study and Kofoky *et al.*, 2006
Saint Augustin	NONE	Yes	+	+	Current study
Anjohibe	NONE	Yes	+	+	Current study

PN: National Park; RS: Special Reserve

RECOMMENDATIONS

1. Conduct a study on the echolocation and wing morphology to predict bat foraging ecology of these species
2. To describe spatial resource partitioning of *Triaenops* spp. in relation to food availability, morphology, echolocation and breeding seasonality of the species,
3. To revise the conservation action plan for *Triaenops* spp
4. Conduct more research on roost availability and home range of some microchiropteran bats including *Triaenops* spp,

ACKNOWLEDGEMENTS

This study could not have been done without the financial assistance and support of the Rufford Small Grant in association Madagasikara Voakajy NGO, to whom I am most grateful. The work was conducted through collaboration between ANGAP, the University of Aberdeen and the Universities of Antananarivo and Toliara in Madagascar.

I would like to thank the Direction of Water and Forest and the National Association for Management of Protected Areas (ANGAP) for granting me the permission to visit the site.

I would like to thank Professor Paul Racey, Dr Jon Russ and Dr Richard Jenkins for their support throughout this project.

We are very grateful to the staff of Project Bemaraha, the Mayor of Saint Augustin for their support, in particular Rindra Rakotoharifetra, Hery Lala Ravelomanantsoa and Gaston,

Invaluable assistance in the field was provided by Honoré Bezandry, Raymond Randrianasolo, Jeannot Zandry Faralahy, Laurent Mahalimby, Stephan Tolisoa, and Tsimahory Tsiverila (TBNP), Augustin Razafianaka, Tata Fanodia and Mme Tiny (Saint Augustin), Edvoara G., Trefindraza and Ambonimanana (Anjohibe)

Most of all I would like to thank my colleagues at Madagasikara Voakajy, especially Félicien Randrianandrianina, Tojo Ramihangihajason, Andrinajoro Rakotoarivelo, Roseline Rampilamanana, Irma Raharinantenaina, Tsibara Mbohoahy and Rado Andriamahaja for their hard work and good company.

PART TWO:

TRAINING & CAPACITY BUILDING

My first Rufford grant funded bat surveys of the forests and caves of karst areas in Madagascar whilist this second on the conservation of trident nose *Triaenops* spp bats which both are cave-roosting species. Those projects were a success, with a wide range of outputs including scientific publications (Kofoky *et al.,* 2006a, b, Goodman, *et al.,* 2005, 2006) and a number of presentations and training sessions held within the study site area. Three students Malagasy from two university of Antananarivo and Toliara, respectively Irma Raharinantenaina, Ramihangihajason Tojo and Manjoazy, who assisted me in the field, were trained on bat research techniques (radio-tracking techniques,..) and analysis and are ongoing to submit their work as masters theses. Others students whom have already their masters on bat ecology (Tsibara Mbohoahy, Felicien Randrianandrianina and Roseline Rampilamana) received respectively 2 months trainings and they become bat experts in Madagascar at the moment.

Apart of the students, As a result of this project, a total of eight (08) ANGAP guides or locale peoples, who previously had no knowledge on bats, were trained to identify the trident nose bats species.

DISSEMINATION AND OUTPUTS

For the results from my work to be of relevance and importance it is vital that the key results and priority recommendations are made available to a wide audience. I therefore used the following activities and outputs to disseminate my results:

- After each fieldwork, I have made a PowerPoint presentation to the ANGAP or to the local authority for dissemination our preliminary results.
- We provided also a document on bat taxonomy for guides (See attached) and a photo CD of bats for Bemaraha project or others
- I will also plan to publish two papers of this work into two international journals of conservation ("Roost site selection" will be submitted to *African Journal of Ecology*, and "Conservation of the Trident nose bats" in *Acta Chiropterologica*)
- Two Malagasy students have completed their theses.

PARTNERS

Dr Anne Marie Razafindraibe, Entomologist from Animal Biology department (DBA), University of Tulear, Madagascar made a short visit to our study site in Saint Augustin to assess the training program and familiarise herself with the bats of Saint Augustin. Dr Richard Jenkins, National Director of MaVoa NGO in Madagascar and Pr Paul Racey from the University of Aberdeen, Co-chairman of the Chiroptera Specialist Group of IUCN's species, co-author of the global conservation status of microchiropteran bats went also to the study sites (TBNP) with me to see and to supervise the work.

University of Toliara, University of Antananarivo and Aberdeen University, Bemaraha Project - National Association for the Management of Protected area in Madagascar (ANGAP) were our collaborators and partners.

SUMMARY OF CAPACITY BUILDING AND OUTPUTS AFTER TWO RUFFORD GRANTS

In summary, since my projects (First and second grants) funded by Rufford Small Grants, a number of outputs are very exciting and I should continue these for the durable conservation of Madagascar unique biodiversity:

- 16 (sixteen) local guides trained

- 8 Malagasy and one british students trained whom five (05) have completed their theses (Felicien Randrianandrianina, Tsibara Mbohoahy, Julie Razafimanahaka, Andrinajoro Rakotoarivelo and Laura Bambini) and four in preparation (Roseline Rampilamanana, Irma Raharinantenaina, Manjoazy and Tojo Ramihangajason)

- Various publications in preparation, in press and published,

1. Goodman, S.M., D. Andriafidison, R. Andrianaivoarivelo, S.G. Cardiff, E. Ifticene, R.K.B. Jenkins, **A.F. Kofoky**, T. Mbohoahy, D. Rakotondravony, J. Ranivo, F. Ratrimomanarivo, J. Razafimanahaka, V. Razakarivony and P.A. Racey. (2005). The distribution and conservation of bats in the dry regions of Madagascar. *Animal Conservation* 8: 153-165.
2. **Kofoky, A.F**., D. Andriafidison, R.B. Jenkins, D. Rakotondravony, F. Ratrimomanarivo, J.H. Razafimanahaka and P.A. Racey. (2006). Habitat use, roost selection and conservation of bats in Tsingy de Bemaraha National Park, Madagascar. *Biodiversity and Conservation.*
3. **Kofoky, A.F**., D. Andriafidison, J.H. Razafimanahaka, R.L. Rampilamanana and R.B. Jenkins. (2006) The first observation of *Myzopoda* sp. (Myzopodidae) roosting in western Madagascar. *African Bat Conservation News* 9: 5-6.
4. **Kofoky, A.F**., F. Randrianandrianina, J. Russ, I.M.O. Raharinantenaina, S.G. Cardiff, R. K. B. Jenkins and P.A. Racey. (In prep). Acoustic identification of some insectivorous bats (Microchiroptera) from Madagascar. *Acta Chiropterologica.*
5. Goodman, S.M., F. Rakotondraparany and **A.F. Kofoky**. (In press) The description of a new species of *Myzopoda* (Myzopodidae: Chiroptera) from western Madagascar. *Mammalian Biology.*
6. Rakotoarivelo, A.A., N. Ranaivoson, O.R. Ramilijaona, A.F. Kofoky, P.A. Racey and R.B.K. Jenkins. (Submitted). Seasonal food habits of five sympatric forest microchiropterans in western Madagascar.
7. Andriafidison, D., A.F. Kofoky, P.A. Racey and R.K.B. Jenkins. (In prep). The morphology, echolocation and diet of the Madagascar free-tailed bat, *Otomops madagascariensis* (Chiroptera: Molossidae). *Acta Chiropterologica*.

At the end, I will encourage RSG to continue support biologists for achieving their objectives!!!!!!!!!

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APPENDIX

Appendix I : Bat identification (Guides training)

FAMILLE DE HIPPOSIDERIDAE
Nez feuillu et nez trident

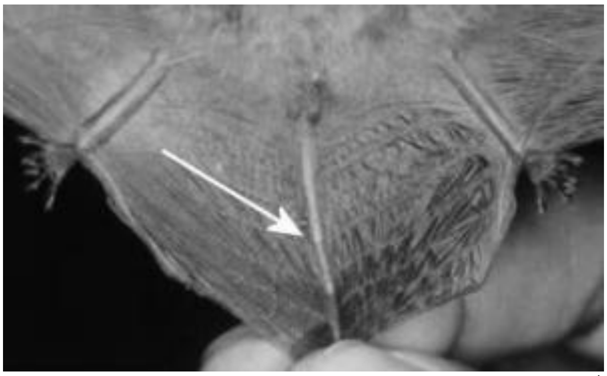
Hipposideros commersoni

Triaenops spp

Triaenops furculus

Triaenops rufus

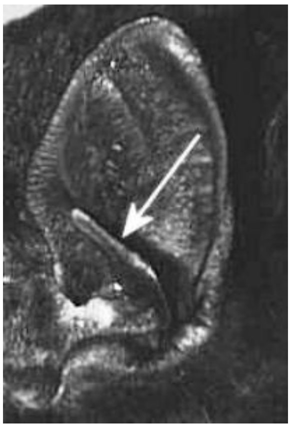
FAMILLE DE VESPERTILIONIDAE



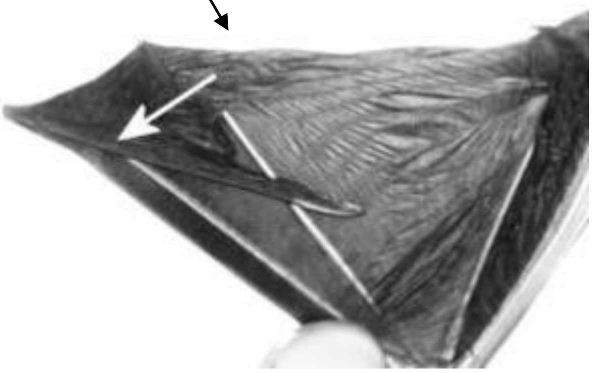
Queue soudée à la membrane alaire

Myotis goudoti

Pipistrellus/Eptesicus sp

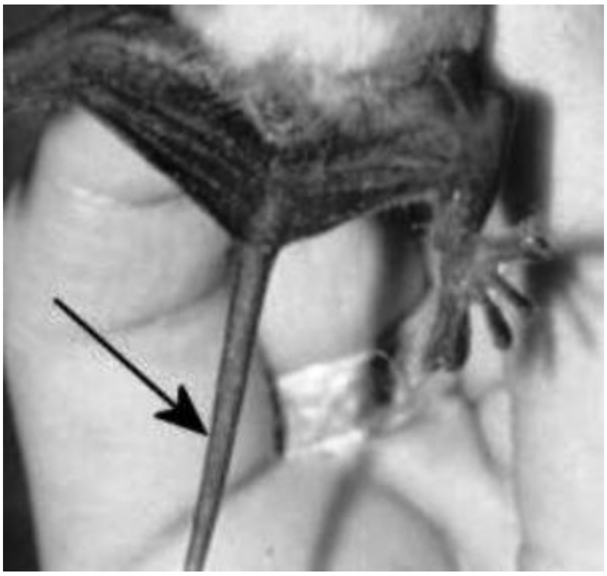


Tragus de *Scotophilus sp*

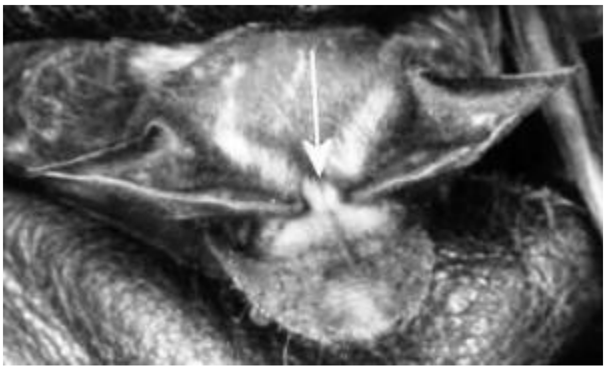


Aile de *Miniopterus spp*

FAMILLE DE MOLOSSIDAE



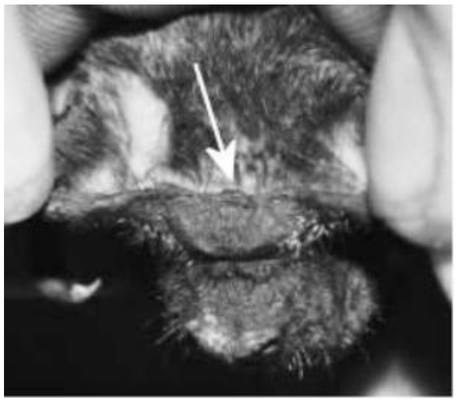
Queue libre



Oreille séparée

-*Mormopterus jugularis*

- *Tadarida fulminans*



Oreille soudée

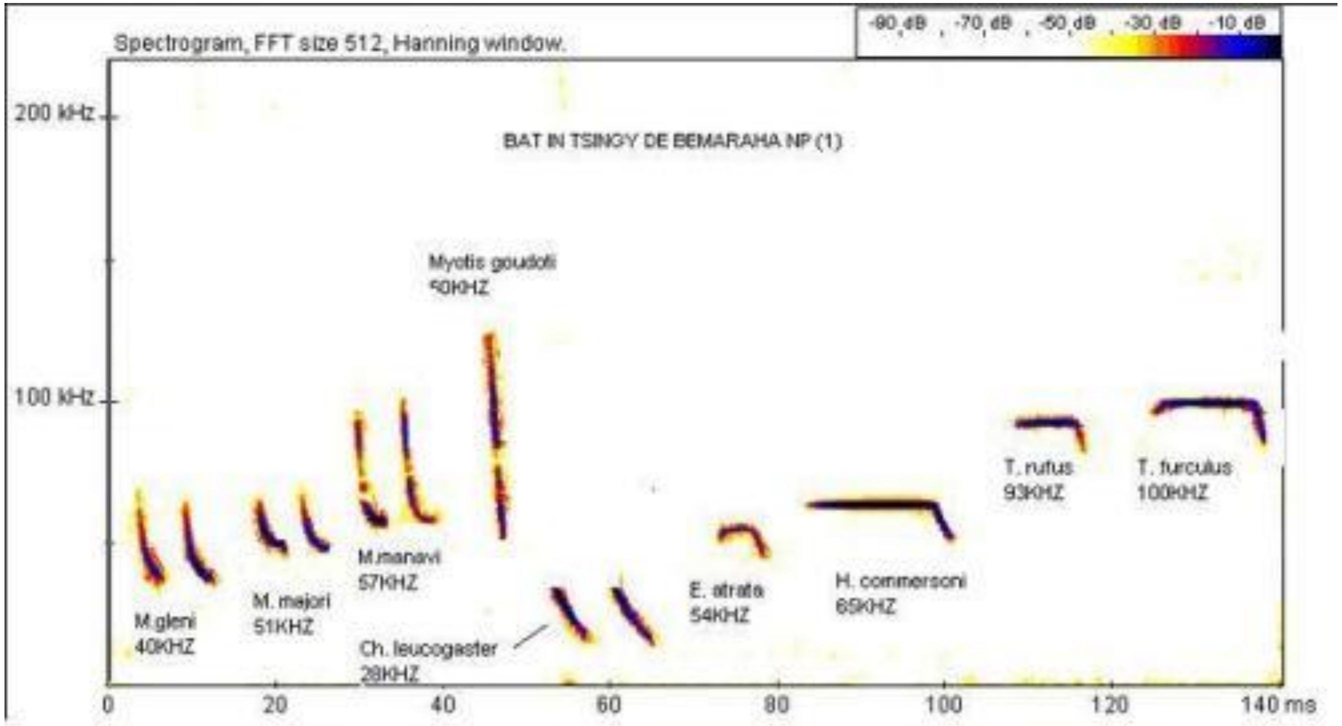
(1) Mops leucostigma

(2) Chaerephon leucogaster

(3) Chaerephon pumilus

(4) Otomops madagacariensis

Appendix II: Free flight, flight cage and release calls from some species in TBNP. Values are the frequency of maximum energy



M = Miniopterus ; Ch = Chaerephon ; E = Emballonura ; H = Hipposideros ; T = Triaenops