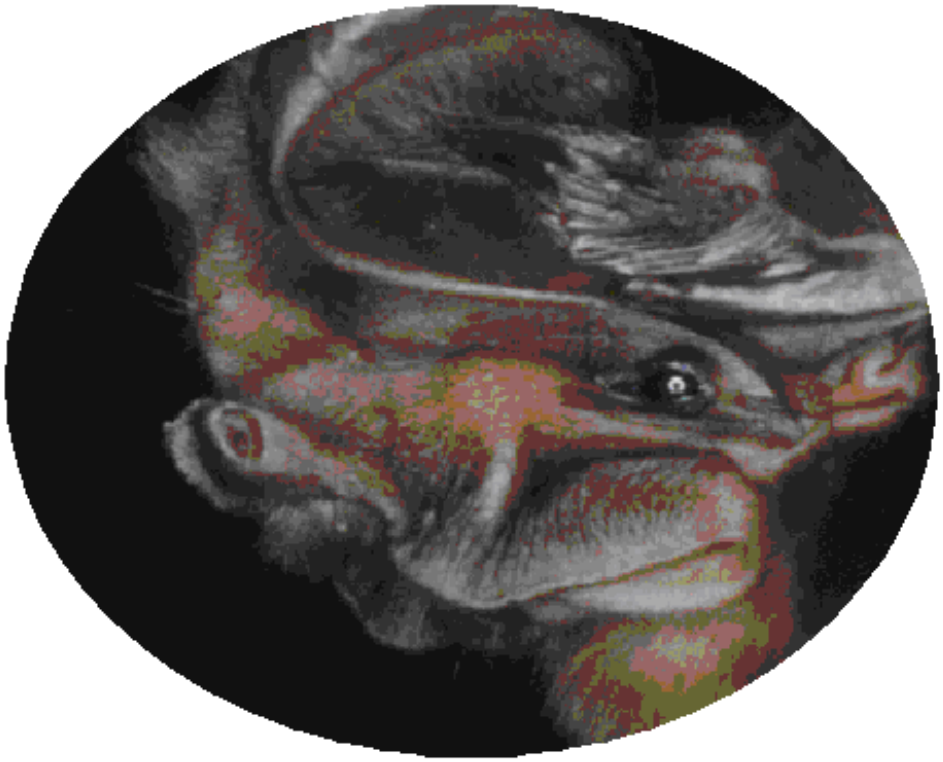
The Bats of Madagascar:

An Identification Guide with Descriptions of Echolocation Calls



Edited by
Daniel Bennett and John Russ

The Bats of Madagascar: A Field Guide with Descriptions of Echolocation Calls

by

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With the generous support of:

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Edited by Daniel Bennett and Jon Russ

A CIP record for this publication is available from the British Library.

"Aberdeen University Madagascar Bat Project" 2001

ISBN 0-9526632-8-7

Published by:
VIPER PRESS
118 Sheffield Road
Glossop
SK13 8QU
Great Britain

Summary

We aimed to catch representatives of all species of Microchiropteran bats living in Madagascar in order to compile a field guide and ultrasound key to the group, allowing inventories of communities to be carried out with the minimum of interference to the animals. The echolocation calls of bats were recorded using time expansion detectors and attempts made to capture individuals of all species present at nine sites in Madagascar. In total 18 species were caught and their echolocation calls recorded and thirty eight hours of recordings made of free-flying bats during our visit from June to September 2000. Four species of insectivorous bat previously known from Madagascar were not found. Of these two have not been sighted for over 70 years and another known from just a single specimen.

Comparative catch per unit effort at Ambanizana in the Masoala peninsular was much lower than during our previous visit in January/February 1999, although the same species were present. Comparison of three capture methods (mist nets, harp trap and flap traps) suggested that flap trapping was the most efficient way to catch bats although the method does not allow for standardised effort. In total about 1,500 bats were caught. All members of the team (except the cooks) were trained in the use of bat traps and ultrasound detectors, handling bats, taxonomy and ultrasound analysis. The team gave demonstrations of bat study techniques to large audiences at all inhabited sites and at workshops in Antananarivo and Toliara. There is sufficient enthusiasm among students in Madagascar to create an effective body of local expertise, and there would be little shortage of skilled volunteers willing to pass on skills from all over the world.

Insectivorous bats are an important component of the unique fauna of Madagascar, but the group has been sadly neglected by scientists, and are among the least known mammals on the island. As a result the population status of all species is undetermined and no conservation strategies have ever been developed for the group. Perhaps more importantly, the taxonomy of the group requires attention because some families require revision and the relationship between Malagasy and continental races of "non endemics" remains unclear. We suggest that the amount of speciation on the island has probably been underestimated and that molecular studies would confirm the existence of more bat species than are currently recognised. To this end a National Reference Collection of bats should be established in Madagascar and the current taxonomy subjected to rigorous scrutiny. An action plan for the Malagasy microchiropterans should be considered an urgent priority, but one based on the current taxonomy might be severely compromised.

To our knowledge, no ecological studies of any species of Malagasy microchiropteran have ever been conducted. The neglect of such an important group on an island with so much unique wildlife and so many serious pressures should be redressed, and we hope this volume will help to do so.

Daniel Bennett and Jon Russ, May 2001.

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Introduction

The aim of this project was to produce a guide to the bats of Madagascar that would allow surveyors to identify animals without destroying them and, where possible, to identify them without capturing them. Until now all identification guides have been based on detailed examination of museum specimens, an approach entirely unsuitable for living animals and inaccessible to all but trained scientists. We hope that this work will stimulate interest in this very neglected group.

The insectivorous bats are among the least studied of the mammalian groups on Madagascar. As a result our knowledge of the group is cursory and incomplete; the taxonomy of bats within some genera is uncertain and virtually nothing is known of the ecology of any species living on the island. This neglect can be attributed to the facts that bats are small, volant and equipped with sensory apparatus that makes them uniquely able to evade scientists, precisely the qualities that make them such a rewarding group to study.

The bats of Madagascar are a somewhat eclectic mix of species of African and Asian origin, together with a few endemics. The degree to which the non-endemic species differ from founder populations is unknown and the origins of some endemic species are uncertain. Of more immediate concern is that massive habitat destruction on the island, which has led to the extinction or demise of many mammalian taxa, has had a completely unknown effect on the insectivorous bats. Without a working knowledge of the taxonomy, distribution and habitat requirements of the animals it is impossible to formulate conservation plans for the group, nor to pinpoint those species in greatest need of protection. Four species of bats recorded from the island have not been seen for at least 50 years and the status of all but the most common species can only be surmised. The suctorial *Myzopoda*, perhaps one of the most beautiful bats in the world and certainly one of the most enigmatic, was previously thought to be extremely rare and in urgent need of protection. Our investigations suggest that the species is in fact more widespread than was though previously, but that other species may be suffering extreme pressure through habitat destruction. We also suggest that some species of bats in Madagascar may remain undescribed

Our efforts in Madagascar have been supported by many people listed elsewhere in this publication. We would like to extend special thanks to Professor Paul Racey at Aberdeen University, whose commitment to the bats of Madagascar is without precedent and whose enthusiasm, advice and persistence has been instrumental to our success.

This volume presents our work on the bats of Madagascar, together with that previously published by other workers. We hope fervently that our efforts will encourage others to make efforts to investigate this little known group, and that they will find the work as enjoyable as we have done.

Acknowledgements

Everyone who worked with us in 1999 and 2000

The Mayor of St Augustin tolerated our attempts to eat his trees, scare away his visitors and burn down his house with great humour.

Matthew Hatchwell and WCS provided access and intermittent logistical support in Masoala and Nosy Mangabe
]
Daniel Rakatondrovy, Madame Emilliene and her colleagues, Universite d'Antananarivo.
.
James McKinnon and Clare Hawkins provided a great deal of practical help

Hesinisina Ramanankirwa of Parc National Andasibe-Mantadia

Pia Demereken

Howard Rosenbaum of WCS kindly made way for us on Nosy Mangabe.

Ian Montgomery, Queen's University, Belfast.

Julian Bayliss

Lars Petterson for his free updates to the BatSound software

Peter Taylor, Durban bat group.

Mark Smyth, NI bat group

James O'Neill, Katie Bloxam and Linda Sadlier.

Nightwatchman, Town Hall, Miary

Paul Racey

Notes on Taxonomy

Taxonomy of Malagasy bats has been discussed by Grandidier and Petit (1932), Dorst (1947)

The last major taxonomic revision of the bats of Madagascar was undertaken by R. L. Peterson of the Royal Ontario Museum in Canada, who died in 1989. The work was completed by Judith Edgar and illustrated by L. Mitchell and published in 1995 (Peterson *et al.* 1995). Wherever possible we have followed their nomenclature. They listed 26 species of Microchiroptera, expressing doubt about the validity of two of them (*Scotophilus borbonicus* and *Pipistrellus sp*.). Of the remaining 24, four species (*Nycteris, Triaenops auritus, Tadarida (Tadarida) fulminans* and *Eptesicus somalicus*) are known from only one or two (simultaneously collected) specimens. We were not able to distinguish *Pipistrellus* from *Eptesicus* in the hand, and so although we have encountered three species from these genera, we are obliged to assign them to "*Eptesicus/Pipistrellus*". A *Tadarida* species caught at St Augustine and Miary could not be identified using the key. Details of these animals are given in the species accounts.

Previous Field Studies

In recent years community surveys of Microchiropterans have been conducted by Pont and Armstrong (1990) recorded 10 species in the Reserve Naturelle Integral de Marojejy in northeastern Madagascar (*Myzopoda. Myotis, Scotophilus, Emballonura, Hipposideros, Tadarida. pumila* and three unidentified *Miniopterus* species). Rasolozaka (1994) recorded 7 species of Microchiroptera (*Taphozous, Scotophilus, Pipistrellus, Tadarida pumila, T. condylurus, T. midas* and *M. jugularis* in the Foret de Zombitse. Goodman (1996) recorded four species of bats (*Rousettus, Hipposideros, Myotis* and *Miniopterus manavi*) at the Reserve Naturelle Integrale d'Andringitra. Hutcheon (1996, 1997) produced a summary list of bats captured at 11 provinces in Madagascar and claimed a total of 13 species at Ankara Reserve. Goodman (1998) found three species at Reserve Speciale d'Anjanaharibe-Sud (*Rousettus, Myotis* and *Miniopterus fraterculus*). Bayliss and Hayes (1999) surveyed bats at two sites in northeastern Madagascar; the Beankorabe area of Makira and Ambanizana in Masoala and found seven and five species. Russ and Bennett (1999) found eleven species of bats (nine Microchiropterans) at Ambanizana and Ambodiforaha. Cottam and Heath (2000) caught five species of Microchiropteran bats around Lac Sahaka, northeastern Madagascar and recognised two species of Triaenops (*T. rufus* and *T. humbolti*) based on colour variations.

Methods

We investigated bat communities at ten sites in Madagascar (Map 1) using time expansion ultrasound detection and four trapping methods.

Ultrasound was recorded using Petterson time expansion bat detectors (models D940, D240 and D240X) onto audio cassettes via Sony WM D6C tape recorders. Bats were recorded in free flight, in flight cages and on release from the hand. Sounds were analysed using Batsound 3.1 (Petterson Elektronik AB, Uppsala, Sweden)**.** Russ (1999) and Russ and Bennett (2000) provide details of analytical techniques.

Bats were caught using flap traps (Figure 1), mist nets (Figure 2), harp traps (Figure 3) and by hand. Flap traps had poles of 5-7 meters and nets of approx. $4m^2$ and were used along streams and paths and outside roosts. Up to 80 two or three shelf mist nets 6-12m long (North Ronaldsay and Japanese types from Spidertech (Sweden) and British Trust for Ornithology (U.K.)) were set on poles or in trees and left open from dusk to dawn. Up to four $1m^2$ harp traps were set in gaps in vegetation and along narrow paths. Nets and traps were inspected regularly.

Figure 1. Using flaptraps on Nosy Mangabe and outside *Otomops* roost near St Augustine.

Figure 2. Intensive mist netting at Andasibe and mist net by roost at Maroantsetra.

Figure 3. Harp trap at Andasibe.

Map 1. Location of study sites.

Bats caught were photographed, weighed and identified using a modified version of Peterson et al. (1995) - see Russ and Bennett (2000). Forearm and total lengths were recorded and sometimes additional measurements were taken. Bats were released in open areas close to point of capture, usually within 90 minutes, and their echolocation recorded. Individuals of each species were also recorded in a flight cage prior to release.

Most recordings were recorded from identified bats as they left the hand or in a flight cage. However, some species were recorded in free flight in an open environment, either recorded before capture with a flap trap, or traced after release. Ultrasound was converted to audible signals via a time-expansion bat detectors (D-980; D-240; D-240X; Petterson Elektronik AB, Uppsala, Sweden). The detector digitally store from 0.8 to 3 seconds of 'real' time, and slows it down by a factor of ten. Time expanded ultrasound was stored on metal cassettes via WM-D6C Sony Professional Walkmans (Sony, Tokyo). The bat detector microphones had a sampling frequency of 350 kHz, resolution 8 bits, and the Walkman had a frequency response of ± 3 dB from 40 kHz – 15 kHz.

From each sequence of calls recorded from each individual bat, measurements were taken from a call picked selectively. Only one call per bat was used, in order to avoid pseudoreplication (Hurlbert, 1984). Care was taken to avoid calls that showed signs of interference, noise, or clipping (Russ, 1999). Measurements were always taken from the fundamental (the call of lowest frequency, under the harmonics), as these generally contained considerably more energy than the higher harmonics, and are the least susceptible to the effects of attenuation. Echolocation calls were analysed using the software program BatSound v3.1 (Petterson Elektronik AB, Uppsala, Sweden). In all cases a Fast Fourier Transform (FFT) setting of 1024 was used with a Hanning window function.

The following parameters were measured from the sonograms and power spectrums:

fmin	minimum frequency (the minimum frequency of the call) (kHz)
fmax	maximum frequency (the maximum frequency of the call) (kHz)
bandwidth	*fmax – fmin* (kHz)
IPI	inter-pulse interval (the duration between the onset of the call and the onset of a subsequent call) (secs)
dur	duration (the duration from the onset of the call to the end of the call) (secs)
fmaxE	the frequency that contains maximum energy (kHz)

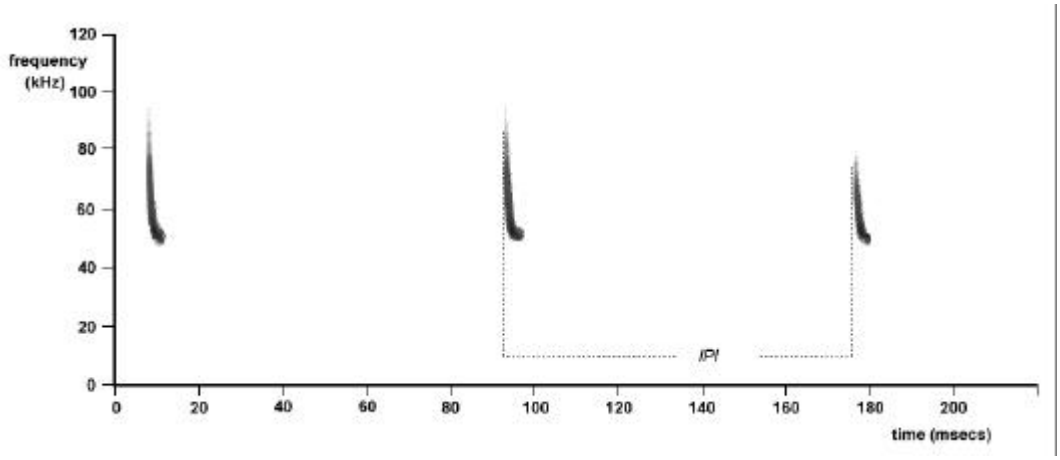


Figure 4. The inter-pulse interval (*IPI*) taken from a sonogram.

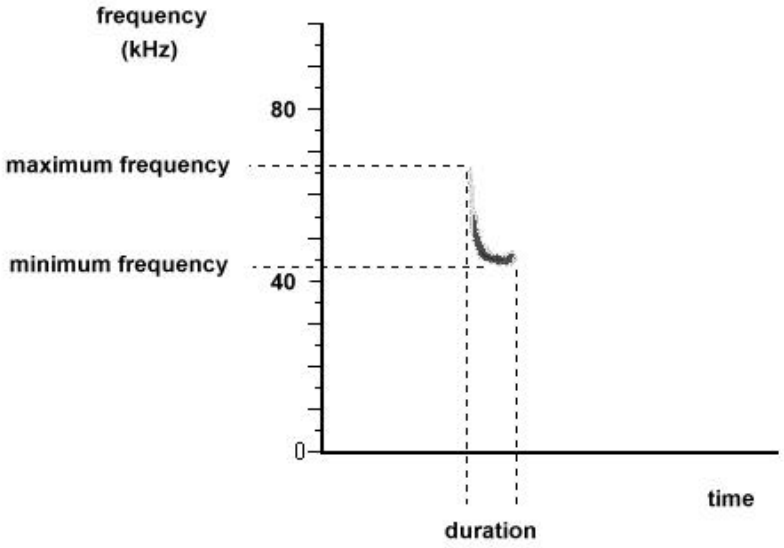


Figure 5. The duration (*dur*), minimum frequency (*fmin*) and maximum frequency (*fmax*) taken from a sonogram.

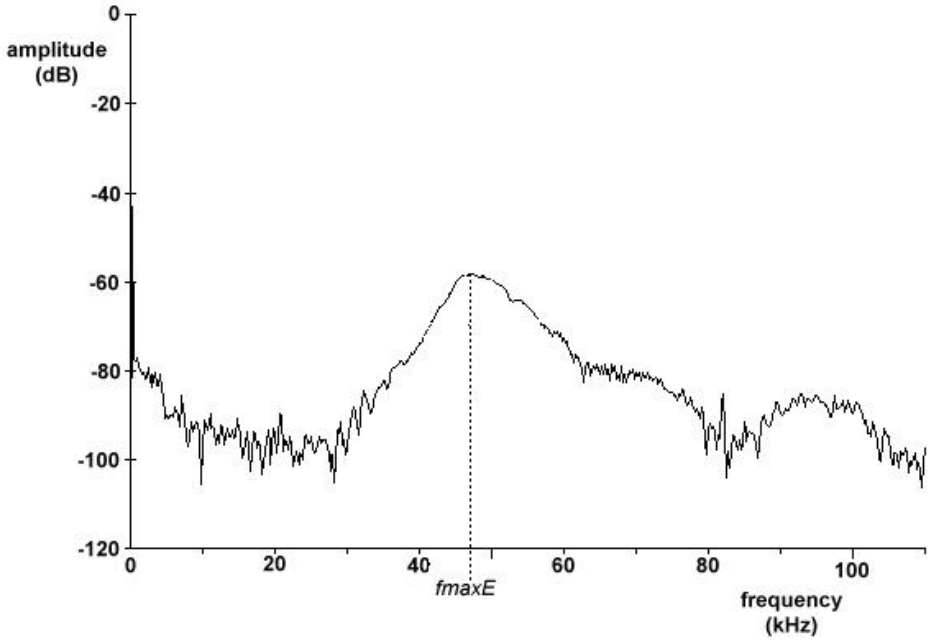


Figure 6. The frequency containing maximum energy (*fmaxE*) taken from the power spectrum.

A threshold setting of 16 was used for all sonograms. *IPI, dur, fmax* and *fmin* were taken from the sonogram (Figures 1 and 2). The *fmaxE* was recorded from the power spectrum (Figure 3).

Data gathered was used to produce a working field guide to bats in Madagascar, based on external appearance, measurements and ultrasound.

Results: Study Sites

Nosy Mangabe
In 1999 the team carried out echolocation surveys at Nosy Mangabe, but lacked a permit to catch bats there. Among the species heard in 1999 was the rare and endemic *Myzopoda aurita*.

In total five species were caught on Nosy Mangabe in 2000; *Emballonura atrata, Miniopterus manavi Miniopterus gleni Hipposideros commersoni* and *Myotis goudoti*. In addition *Myzopoda aurita* was heard and seen but not caught. Sixty eight mist net nights caught five bats of four species, three species were caught in flap traps and one species collected by hand. Bats were caught along paths and over rivers.

Table 1. Summary of bat catches at Nosy Mangabe

Species	Mistnets	Flaptraps	Other
Emballonura atrata	**1**	**1**	**2**
Miniopterus manavi	**1**	**0**	**0**
Miniopterus gleni	**0**	**2**	**0**
Hipposideros commersoni	**1**	**0**	**0**
Myotis goudoti	**2**	**0**	**0**

Ambanizana
Five species of insectivorous bats were caught at Ambanizana between 4th and 8th of August. In total 32 bats were caught; 20 in flaptraps and 12 in mist nets. One hundred and fifteen mist net nights caught 12 bats of four species. Catch per unit effort was much lower than in February 1999, when 31 mist net nights caught a total of 31 bats (16 *Rousettus* and 15 insectivorous bats). Bats were caught in forest clearings, along rivers and paths and at the edges of paddy fields.

Table 2. Summary of bat catches at Ambanizana.

Species	Mistnets	Flaptraps	Other
Rousettus	**8**	**0**	**0**
Emballonura atratra	**0**	**7**	**0**
Miniopterus manavi	**0**	**13**	**0**
Miniopterus gleni	**1**	**0**	**0**
Scotophilus robustus	**1**	**0**	**0**
Tadarida (Mops) leucostigma	**2**	**0**	**0**

Maroantsetra
At Maroantsetra the team sampled bats from a large roost of *Tadarida leucostigma* in a church tower using flap traps.

Ambodiadabo
The village of Abodiadabo (nicknamed Mudsville) was visited in order to sample the bat community in the northeast away from the coast. In total 14 bats of five species were caught. One individual was a *Miniopterus* that we were unable to assign to species. Despite effort of 160 mist net nights over five days only one bat (*Myzopoda aurit*a) was caught in a mist net. Nets were set along streams and paths and at the edge of paddy fields.

Table 3. Summary of bat catches at Abodiadabo

Species	Mistnets	Flaptraps	Other
Triaenops rufus	**0**	**1**	**0**
Emballonura atratra	**0**	**4**	**0**
Miniopterus manavi	**0**	**1**	**0**
Miniopterus gleni	**0**	**5**	**0**
Miniopterus sp.	**0**	**1**	**0**
Myzopoda aurita	**1**	**1**	**0**

Lac Anosy
A large lake in the middle of Antananarivo. Eight bats of the *Pipistrellus*/*Eptesicus* group were caught with flap traps.

Parc National Andasibe-Mantadia
The team made two visits to this area, in July and August. Despite massive mist netting effort (325 mistnet nights over ten days) no bats were caught by this method. In total 27 individuals of seven species were captured. *Myzopoda aurita* was heard once at this site, but not captured.Nets were set along and across rivers and lakes, on paths and in cleared areas.

Table 4. Summary of bat catches at Andasibe.

Species	Mistnets	Flaptraps	Harptraps	Other
Miniopterus manavi	**0**	**5**	**10**	**0**
Miniopterus majori	**0**	**1**	**0**	**0**
Myotis goudoti	**0**	**1**	**0**	**0**
Mormopterus jugularis	**0**	**0**	**0**	**1**
Tadarida (Mops) leucostigma	**0**	**0**	**0**	**3**
Tadarida pumila	**0**	**4**	**0**	**0**
Eptesicus/Pipistrellus	**0**	**2**	**0**	**0**

St. Augustin
At St Augustin bats were caught in mistnets and flaptraps outside roosts in buildings and caves. Because of this positioning effort was not recorded. In total at least 154 individuals of ten species were caught; *Otomops, Tadarida leucogaster, T.leucostigma, M. jugularis, T. sp., Eptesicus/Pipistrellus sp., Triaenops rufus, T. furculus, Miniopterus manavi* and *M. gleni*.

Miary
In the hope of finding *Tadarida midas* team members visited Miary, close to St Augustine, where the holotype was collected in the nineteenth century. Having secured permission from the mayor, mistnets were set outside five roosts in the centre of the village. Unfortunately at dusk, miscreants among a crowd of observers began catapulting bats caught in nets before

turning their attention to the bat workers themselves, pelting them with stones and harassing female members of the team. In the interests of safety bats were released as quickly as possible. We estimate 300 bats were caught (*Tadarida (Mops) leucostigma, M. jugularis, Tadarida sp.*) of which about 120 were killed. This is the only time we have experienced threats to personal security in Madagascar.

Ifaty
No bats were seen or heard at Ifaty, a coastal resort about 40 km north of Toliara.

Results: Echolocation

Data analysis
As the parameters inter-pulse interval (*IPI*), duration (*dur*), the frequency containing maximum energy (*fmaxE*) and bandwidth were substantially skewed, the data were square-root transformed, which considerably normalised the data.

Multiple Discriminant Function Analysis
To test the validity of the species groups to which the echolocation calls were assigned in the field i.e. before analysis, a multivariate discriminate function analysis was performed. This allowed the analysis of unidentified species to investigate whether they were statistically distinct based on the measured parameters of their echolocation. The analysis also identified which variables accounted for the greatest variation between the groups. The parameters *fmin* and *fmax* were strongly correlated to *fmaxE* and were therefore omitted from the analysis. *fmaxE, dur*, *IPI* and *bandwidth* were included in the analysis.

Species were assigned to the following groups based on the nature of their echolocation calls (CF = constant frequency, FM = frequency modulated):

CF group
Hipposideros. commersoni
Triaenops rufus
Triaenops furculus
Emballonura atrata

FM group
Myotis goudoti
Rousettus madagascariensis

FM/CF group - Vespertilionidae
***Pipistrellus* spp. (Andasibe)**
***Pipistrellus* spp. (Antananarivo)**
***Eptesicus* spp.**
Miniopterus gleni
M. majori
M. manavi
Scotophilus robustus

FM/CF group – Mollosidae
Tadarida (Mops) leucostigma
T. (Chaerephon) leucogaster

T. pumila
M. jugularis
O. madagascariensis

Recordings were obtained from the following bat species:

E. atrata, *Eptesicus* spp., *H. commersoni*, *M. gleni*, *M. majori*, *M. manavi*, *My. goudot*i, *O. madagascariensis*, *Pipistrellus* spp. (Andasibe), *Pipistrellus* spp. (Antananarivo), *R. madagascariensis*, *S. robustus*, *M. jugularis*, *T. (Chaerephon) leucogaster*, *T. (Mops) leucostigma*, *T. pumila*, *T. rufus*, *T. furculus*. General description of calls are given in the identification guide. The mean values of measured parameters of the echolocation calls of all recorded species are presented in Table 5. Standard deviations are presented in Table 6.

Multivariate analysis
To test the statistical validity of the species groups the echolocation calls were assigned to, a multivariate discriminate function analysis was performed. The analysis also identified which variables accounted for the greatest variation between the groups. The variables *fmaxE*, *IPI*, *dur* and *bandwidth* were all included. The transformed data were used.

Three canonical discriminant functions were obtained for the species groups. Eigenvalues indicated the strength of the functions in differentiating one group from another. Function 1, the strongest function, accounted for 91.38% of the overall variation between groups (Table 3). Chi-square analysis suggested that on functions 1, 2, and 3, the groups varied significantly (Table 4).

Correlations between predictors and discriminant functions are displayed in the structure matrix (Table 5). The importance ranking was based on Comrey (1978). For function 1, *fmaxE* (positively weighted) accounted for over 50% of the overlapping variance. For function 2, both *dur* (negatively weighed) and *bandwidth* (positively weighted) accounted for over 50% of the overlapping variance. For function 3, both *bandwidth* and *dur* (both positively weighed) accounted for over 50% of the overlapping variance.

Multiple discriminant analysis suggested that 72.25% of the individuals were classified correctly into independently determined groups (Table 5).

CF group

The CF echolocating bats *H. commersoni*, *T. rufus* and *T. furculus* were 100% correctly classified to group and therefore they can be identified with 100% accuracy from their echolocation calls. *E. atrata* was correctly classified in 95% of cases, the remaining 5% (1 call) being assigned to *M. manavi*.

FM group

The calls of *R. madagascariensis* were 50% correctly assigned to group with the other 50% being assigned to *T. (Chaerephon) leucogaster*. Calls of *My. goudoti* were 47% correctly assigned to the *My. goudoti* species, while the remaining percentage was assigned to *M. manavi*, *M. majori*, *E. atrata* and *T. rufus*.

FM/CF group – vespertilionidae

Calls of *Eptesicus* spp., *M. majori*, *Pipistrellus* spp. (Antananarivo) and *S. robustus* were 100% correctly assigned. Calls of *M. manavi* were 56% correctly assigned to the *M. manavi* species with other calls of this species being assigned to *E. atrata* (22%), *M. majori* (11%) and *My. goudoti* (11%). 78% of calls of *M. gleni* were correctly classified with the remaining 22% being assigned to *Pipistrellus* spp. (Andasibe). 61% of calls of *Pipistrellus* spp. (Antananarivo) were correctly assigned with the rest of the calls being assigned to *Eptesicus* spp. (22%) and *M. gleni* (17%).

FM/CF group – Mollosidae

The calls of *T. (Chaerephon) leucogaster* were 100% correctly classified. Calls of *O. madagascariensis* were 77% correctly assigned to *O madagascariensis* with 23% being assigned to *R. madagascariensis*. 22% of calls of *M. jugularis* were correctly assigned to the *M. jugularis* spp. with the remaining calls being assigned to *Pipistrellus* spp. (Andasibe) (33%), *Pipistrellus* spp. (11%) and *T. pumila* (33%). The calls of *T. (Mops) leucostigma* were 21% correctly classified to *T. (Mops) leucostigma* with the remaining calls being assigned to *Eptesicus* spp. (11%), *M. majori* (5%), *O. madagascariensis* (5%), *S. robustus* (5%), *T. (Chaerephon) leucogaster* (42%) and *T. pumila* (11%). Calls of *T. pumila* were 56% correctly classified to *T. pumila* with the remaining calls being classified to *R. madagascariensis* (11%) and *M. jugularis* (33%).

Table 5. Means for each recorded parameter for all species. Time measurements are in ms, frequency measurements are in kHz. IPI = inter-pulse interval, dur = duration, fmaxE = frequency containing maximum energy. Eatrat = *E. atrata*, Eptes = *Eptesicus* spp., Hcomm = *H. commersoni*, Mglen = *M. gleni*, Mmaj = *M. majori*, Mman = *M. manavi*, Myotis = *M. goudoti*, Omad = *O. madagascariensis*, Pip(P) = *Pipistrellus* spp. (Andasibe), Pip(T) = *Pipistrellus* spp. (Antananarivo), Rmad = *R. madagascariensis*, Srob = *S. robustus*, Tjug = *M. jugularis*, Tleucos = *T. leucostigma*, Tleugog = *T. leucogaste*r, Tpum = *T. pumila*, Tfur = *T. furculus*, Truf = *T. rufus*

Species	***IPI***	dur	fmaxE	bandwidth
Eatrat	93.8900	7.3000	54.7350	2.6200
Eptes	90.0000	4.9400	46.1600	16.6000
Hcomm	61.8167	19.6917	64.3083	0.9833
Mglen	73.3889	4.2644	42.3667	49.9444
Mmaj	74.6250	5.2250	51.2375	23.6375
Mman	65.6000	4.2222	58.9000	12.2111
Myotis	56.0412	3.8706	63.5588	21.7412
Omad	333.9231	15.0000	16.0200	8.0923
Pip(P)	52.3333	5.4700	40.9667	39.3333
Pip(T)	126.0667	4.8817	41.5056	25.7667
Rmad	55.0000	17.5000	29.3500	25.8000
Srob	219.7500	6.9750	36.2500	5.5000
Tjug	191.6889	11.4800	31.6667	19.8556
Tleucos	92.3526	9.5263	31.1421	15.7579
Tleugog	72.3333	8.9767	28.1000	19.1333
Tpum	173.6000	13.3444	27.8222	17.9556
Tfur	43.7583	16.8083	111.7833	20.3667
Truf	59.6273	7.8100	90.3364	25.4455

Table 6. Standard deviations for each recorded parameter for all species. Time measurements are in ms, frequency measurements are in kHz. IPI = inter-pulse interval, dur = duration, fmaxE = frequency containing maximum energy. Eatrat = *E. atrata*, Eptes = *Eptesicus* spp., Hcomm = *H. commersoni*, Mglen = *M. gleni*, Mmaj = *M. majori*, Mman = *M. manavi*, Myotis = *M. goudoti*, Omad = *O. madagascariensis*, Pip(P) = *Pipistrellus* spp. (Andasibe), Pip(T) = *Pipistrellus* spp. (Antananarivo), Rmad = *R. madagascariensis*, Srob = *S. robustus*, Tjug = *M. jugularis*, Tleucos = *T. leucostigma*, Tleugog = *T. leucogaste*r, Tpum = *T. pumila*, Tfur = *T. furculus*, Truf = *T. rufus*

Species	IPI	dur	fmaxE	bandwidth
Eatrat	38.8149	1.7290	1.4748	2.8254
Eptes	18.8282	0.7301	1.8243	7.9171
Hcomm	26.0505	2.2645	1.1373	0.2125
Mglen	38.2357	1.2460	0.9500	5.2840
Mmaj	12.0215	1.0854	1.0917	9.2130
Mman	27.8306	1.2091	3.2886	6.9892
Myotis	22.2512	1.0469	7.7196	8.9320
Omad	203.6281	13.1851	2.3229	2.6688
Pip(P)	3.4530	0.0265	1.7039	1.0408
Pip(T)	46.6311	1.1339	2.4426	10.9673
Rmad	42.4264	14.8492	7.0004	15.6978
Srob	67.1038	0.0500	0.1915	0.9345
Tjug	177.7814	6.7533	7.7666	13.6324
Tleucos	80.1880	2.7033	8.2082	7.0095
Tleugog	10.0664	0.0404	0.1732	0.4163
Tpum	93.2565	4.4360	4.1961	9.7332
Tfur	19.4400	1.0975	0.8376	2.5875
Truf	70.6840	1.4732	0.6423	18.9181

Table 7. Eigenvalues from Multiple Discriminant function analysis species based on measured parameters of their echolocation calls. Percentages, cumulative percentages and correlations are given for each function derived from the analysis.

	Eigenvalue	*Percent*	*Cumulative*	*Correlation*
1	36.2592	91.38%	91.38%	0.9865
2	2.4734	6.23%	97.61%	0.8439
3	0.9489	2.39%	100.00%	0.6978

Table 8. Canonical statistics for differences between groups on functions 1 to 3.

	Wilks' lambda	*Chi-Square*	*DoF*	*Significance*
				< 0.001
0	0.0026	1067.8295	68	<0.001
1	0.0956	420.2258	48	< 0.001
2	0.3320	197.3463	30	< 0.001

Table 9. Structure matrix. Importance is ranked according to Comrey (1973); * = poor (10%) overlapping variance, ** = fair (20% overlapping variance), *** = good (30% overlapping variance), **** = very good (40% overlapping variance) and ***** = excellent (50% overlapping variance).

	Function 1	*Function 2*	*Function 3*
IPI	-0.0997	-0.1396	0.0761
dur	0.0297	-0.5642*****	0.7596*****
fmaxE	0.9470*****	0.2405	0.0039
bandwidth	-0.0033	0.7838*****	0.5758*****

Table 10 (over) Classification of individuals into species groups. Eatrat = *E. atrata*, Eptes = *Eptesicus* spp., Hcomm = *H. commersoni*, Mglen = *M. gleni*, Mmaj = *M. majori*, Mman = *M. manavi*, Myotis = *M. goudoti*, Omad = *O. madagascariensis*, Pip(P) = *Pipistrellus* spp. (Andasibe), Pip(T) = *Pipistrellus* spp. (Antananarivo), Rmad = *R. madagascariensis*, Srob = *S. robustus*, Tjug = *M. jugularis*, Tleucos = *T. (Mops) leucostigma*, Tleugog = *T. leucogaste*r, Tpum = *T. pumila*, Tfur = *T. furculus*, Truf = *T. rufus*

		Predicted																	
		Eatrat	Eptes	Hcomm	Mglen	Mmaj	Mman	Mgoud	Omad	Pip(P)	Pip(T)	Rmad	Srob	Tjug	Tleucos	Tleugog	Tpum	Tfur	Truf
Actual	Eatrat	19	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
		95.00%	0.00%	0.00%	0.00%	0.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Eptes	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Hcomm	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Mglen	0	0	0	7	0	0	0	0	2	0	0	0	0	0	0	0	0	0
		0.00%	0.00%	0.00%	77.78%	0.00%	0.00%	0.00%	0.00%	22.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Mmaj	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0
		0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Mman	2	0	0	0	1	5	1	0	0	0	0	0	0	0	0	0	0	0
		22.22%	0.00%	0.00%	0.00%	11.11%	55.56%	11.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Mgoud	1	0	0	0	3	4	8	0	0	0	0	0	0	0	0	0	0	1
		5.88%	0.00%	0.00%	0.00%	17.65%	23.53%	47.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.88%
	Omad	0	0	0	0	0	0	0	10	0	0	3	0	0	0	0	0	0	0
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	76.92%	0.00%	0.00%	23.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Pip(P)	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Pip(T)	0	4	0	3	0	0	0	0	0	11	0	0	0	0	0	0	0	0
		0.00%	22.22%	0.00%	16.67%	0.00%	0.00%	0.00%	0.00%	0.00%	61.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Rmad	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	50.00%	0.00%	0.00%	0.00%	50.00%	0.00%	0.00%	0.00%
	Srob	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Tjug	0	0	0	0	0	0	0	0	3	1	0	0	2	0	0	3	0	0
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	33.33%	11.11%	0.00%	0.00%	22.22%	0.00%	0.00%	33.33%	0.00%	0.00%
	Tleucos	0	2	0	0	1	0	0	1	0	0	0	1	0	4	8	2	0	0
		0.00%	10.53%	0.00%	0.00%	5.26%	0.00%	0.00%	5.26%	0.00%	0.00%	0.00%	5.26%	0.00%	21.05%	42.11%	10.53%	0.00%	0.00%
	Tleugog	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%
	Tpum	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	5	0	0
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	11.11%	0.00%	33.33%	0.00%	0.00%	55.56%	0.00%	0.00%
	Tfur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
	Truf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%

Figure 7. L'equipe de Chauve-Souris, 1999 and 2000

DISCUSSION

We have demonstrated that ultrasound can be a powerful tool in the study of microchiropteran bats in Madagascar. It allows predictions of species richness to be made without trapping effort, enables individual bats to be "hunted" based on their movement patterns. It is particularly useful because it can positively affirm the presence of very rare species in the community, whose capture would require enormous effort. However, used alone, ultrasound is unlikely to provide a complete species inventory at any site in Madagascar, because some species produce low intensity. Although some species can be identified easily even with a heterodyne detector (most notably *Myzopoda aurita*), identification of others is prone to ambiguity.

The described analysis provides a method of species identification that is independent from the researchers subjectivity and ability and has been used with varying degrees of success to discriminate between European species of bat (e.g. Zingg, 1990; Vaughan, Jones & Harris, 1997; Russ, 1999). However, in Europe, the situation is different to that in Madagascar as most, if not all, of the bat species have been identified and well studied and bats can usually be identified and recorded in flight. In the present study data are heavily skewed towards calls that are produced in a cluttered environment which are known to be problematic when attempting to differentiate between species (e.g. Russ, 1999).

Bat calls are very flexible in their structure, perhaps the most important of these being the relationship between call 'shape' and the degree of clutter in the environment (see Russ, 1999 for influences upon echolocation structure). In the present study, it was the researchers ability to utilise this knowledge to make predictions about the calls of bats in their natural environments (usually relatively clutter free) based on the recorded calls of bats upon release (cluttered situations) which allowed calls to be assigned to species very quickly. For example, during the study, recordings of *M.manavi* and *M. gleni* had shown that the *fmaxE* of these species was about 58kHz and 40kHz respectively. As it is known that *fmaxE* is usually negatively correlated with forearm length, this could be used to predict the echolocation calls of the intermediary species, *M. majori* as being about 50kHz. This prediction proved to be correct once the species had been captured and recorded (actual *fmaxE* = 51kHz). This method also proved useful for both the Hipposideridae and the Mollosidae.

The analysis often suggested that calls of some species should be assigned to a different species, an example being the classification of *O. madagascariensis* calls as *R. madagascariensis*. From observing sonograms of the calls of these two species, it is impossible to misclassify them, because the calls of *O. madagascariensis* are long duration, low frequency constant frequency calls whilst- the calls of *R. madagascariensis* are frequency modulated and of very short duration. This misclassification also occurred with other species such as *E. atrata*, another species easily identified when its calls are observed as sonograms. Therefore, researcher independent techniques such as the multiple discriminant function analysis have only a limited role in assisting the assigning of calls to species.

A challenging and extremely useful aspect of use of ultrasound is in the study of communities with four or more sympatric species of the *Tadarida* complex. These species are very highflying aerial hawkers that are difficult to catch away from their roosts. However their calls are loud and easily recorded from the ground. Because recordings of their calls in cluttered environments do not allow predictions to be made about their echolocation calls, recordings of known individuals foraging in open air are required. Once this has been accomplished species assignation should be straightforward. Figure 8 shows the calls of three bats of the family

Mollosidae recorded in free flight. in free flight over Lak Anosy in Antananarivo. Note the variation in the echolocation calls of species A, associated with the approach to an insect, the terminal part of the call sequence being typical of the species in a high degree of clutter. In 'normal' situations the calls of this species would be more CF."

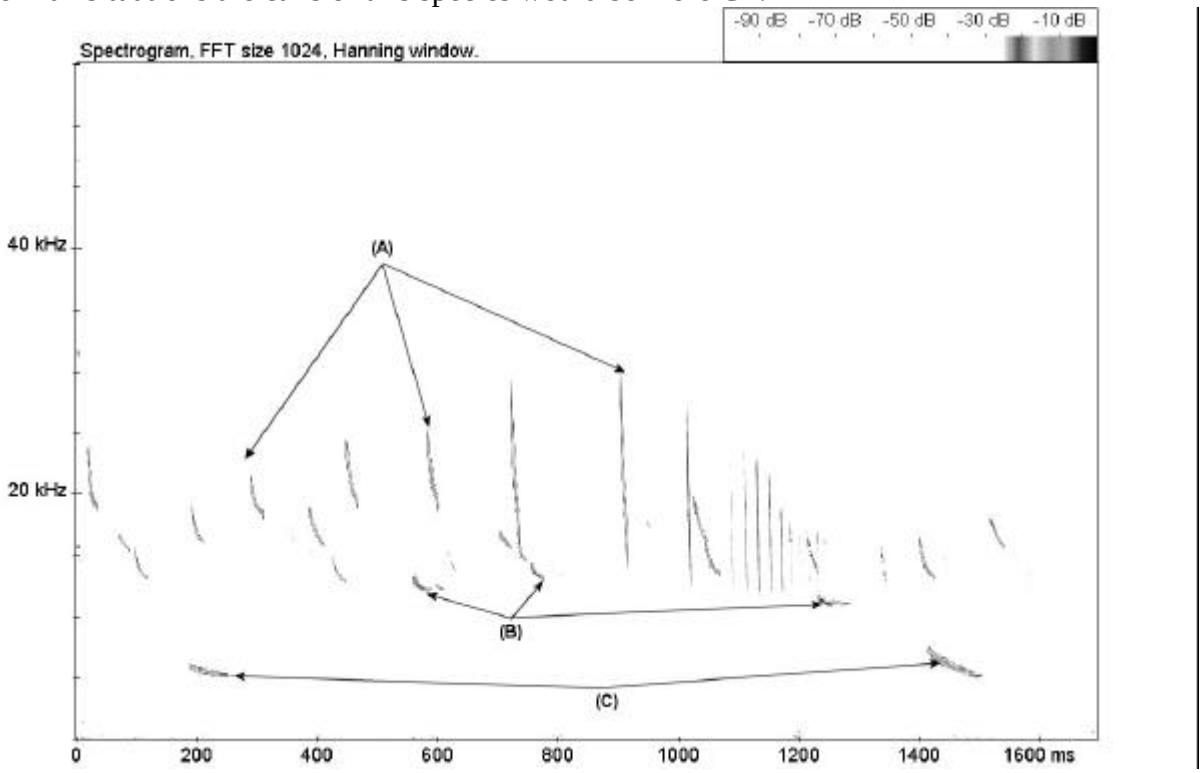


Figure 8. Calls of three species of mollosid bats in free flight over Lac Anosy, Antananarivo.

Conclusions and Recommendations

- *Myzopoda aurita, Scotophilus borbonicus, Tadarida (Chaerephon) leucogaster Triaenops furculus* and *Otomops madagascariensis* should be considered priority species for further research. They are always the rarest members of communities and their distributions appear limited.

- We consider that *Tadarida (Chaerephon) leucostigma* is unlikely to be threatened in Madagascar because it is found in large numbers in many human habitatations.

- Efforts should be made to locate *Tadarida midas* and other species known from single specimens.

- The taxonomy of the *Eptesicus*/*Pipistrellus* complex requires further revision and refinement

NOTES:

Details of locations and general distributions can be found in Peterson *et al*. (1995) and Garbutt (1999).

Weights are in grams and other measurements are in mm. They include measurements of live individuals taken by us and measurements of museum specimens by Peterson *et al* (1995)

REPOBLIKAN'I MADAGASIKARA
Tanindrazana-Fahafahana-Fandrosoana

MINISTERE DES EAUX ET FORETS
SECRETARIAT GENERAL
DIRECTION GENERALE
DES EAUX ET FORETS
DIRECTION DE LA GESTION DURABLE
DES RESSOURCES FORESTIERES
SERVICE DE LA CONSERVATION
DE LA BIODIVERSITE

AUTORISATION DE - RECHERCHE
- ETUDE

N° 142 MEFE/SG/DGEF/DGDRF/SCB

NOM : BENNET
PRENOM : Daniel
ADRESSE : B.P. 8500 Antananarivo
FONCTION : Chercheur
ACCOMPAGNE DE : Kofoky Félix - D. Bennet - Ratrimomanarivo F. - Raherisarisena Martin - Ralisoamalala Rosette - Rakamiarison S. - Razafindraboto N. - Razakarivony V - Randrianirina E.F - Keith Ross - Jon Russ - James O'Neill - L. Marshall.-
ORGANISME DE TUTELLE : W.C.S.

EST AUTORISE (E) A FAIRE DES RECHERCHES/ETUDES DANS : les régions de : Toliara - Sakaraha - Ranohira - Ihosy - Ambalavao - Fianarantsoa - Vevembe.-
Les Aires Protégées de : Tsimanampetsotsa - Zombitse - Vohibasia - Isalo.-
MENTION SPECIALE EVENTUELLE :
- Etude sur les microchiroptères malgaches, construction d'un catalogue de référence sur les écholocations des chauve-souris et développement de nouvelles stratégies de piegeages pour faciliter l'identification des chauve-souris insectivores. Capture avec relâche après étude et observations.
(Avis favorable du CAFF/CORE du 08.08.2000)

DUREEE : QUATRE (04) MOIS

NB : Le bénéficiaire de cette autorisation doit remettre à la Direction de la Gestion Durable des Ressources Forestières, en quatre (04) exemplaires et EN FRANÇAIS , le rapport préliminaire à la fin de sa mission et le rapport final avec les résultat des recherches au plus tard deux ans après la mission.
Le bénéficiaire de la présente autorisation doit prendre l'autorisation d'entrée dans les Aires Protégées auprès de l'ANGAP (Association National pour la Gestion des Aires Protégées) à Ambatobe Antananarivo.

Antananarivo, le 08 AOUT 2000

P. LE DIRECTEUR DE LA GESTION DURABLE
DES RESSSOURCES FORESTIERES po.

RAKOTONIRINA

AMPLIATIONS :
- CAFF / CORE
- DIREF Fianarantsoa
- CIREF Toliara
- ANGAP
-Chef de Postes des A.P ci-dessus

Pteropus rufus (Geoffroy, 1803)

Suborder: MEGACHIROPTERA	
Family: PTEROPOPIDAE	**EN: Madagascar flying fox**
Genus: *PTEROPUS*	**FR: Renard volant malgache**

Figure 9. *Pteropus rufus*, Masoala

The endemic Madagascar flying fox, *Pteropus rufus* is the largest of all the bats in Madagascar. The skull is long. The ears are also long, pointed, widely separated, and have horizontal creases going to the tip. The fur meets on the top of the head and is partly pale yellow or orange, contrasting sharply with the snout, the back, and the brown hindquarters. The colouration of the coat and absence of a tail distinguishes this species immediately from *Eidolon* or *Rousettus*, the two other members of the Megachiroptera present in Madagascar. The first premolar (P1) is often very redundant or absent in this species. Some authors have suggested a subspecies, *Pteropus rufus princeps*, separated from *P. rufus* by such morphological measurements as having a larger fifth metacarpal. However, it is generally agreed that the existence of this species is unlikely.

Characteristics	**Measurements**
Mass	500-750
Total length	234-270
Foot	52-62
Ear	29-40
Tibia	73-87
Wingspan	1200-1240
Forearm	154-172
5th Metacarpal	109-118
Skull length	69-74
Condylobasal length	67-72

Echolocation: None

Eidolon dupreanum (Pollen, 1866)

Suborder: MEGACHIROPTERA	
Family: PTEROPOPIDAE	**EN: Madagascar straw-coloured fruit bat**
Genus: *EIDOLON*	**FR: Roussette malgache couleur paille**

Figure 10. *Eidolon helvum*, Bui National Park, Ghana

Malagasy specimens have been included in the African form *helvum*, but are now considered to merit specific rank and are therefore endemic to Madagascar. Bats are light brown or yellow brown on the back and chamois-olive or brown underneath. Males have hair that is very obviously yellow on part of the neck glands. The coat is slightly shorter on the back. The skull is long and thin. The pattern of colouration and the short tail allows easy separation of this species with *Pteropus rufus*, and the colouration of the body combined with the body size make this easily separable from *Rousettus madagascariensis*. Males are slightly larger than females.

Characteristics	**Measurements**
Mass	235-346
Total length	190-215
Tail length	13-20
Foot	35-46
Ear	32-36
Tibia	50-62
Forearm	115-131
5th Metacarpal	73-88
Wingspan	750-950
Skull length	51-59
Condylobasal length	48-56

Echolocation: None

Rousettus madagascariensis (Grandidier, 1928)

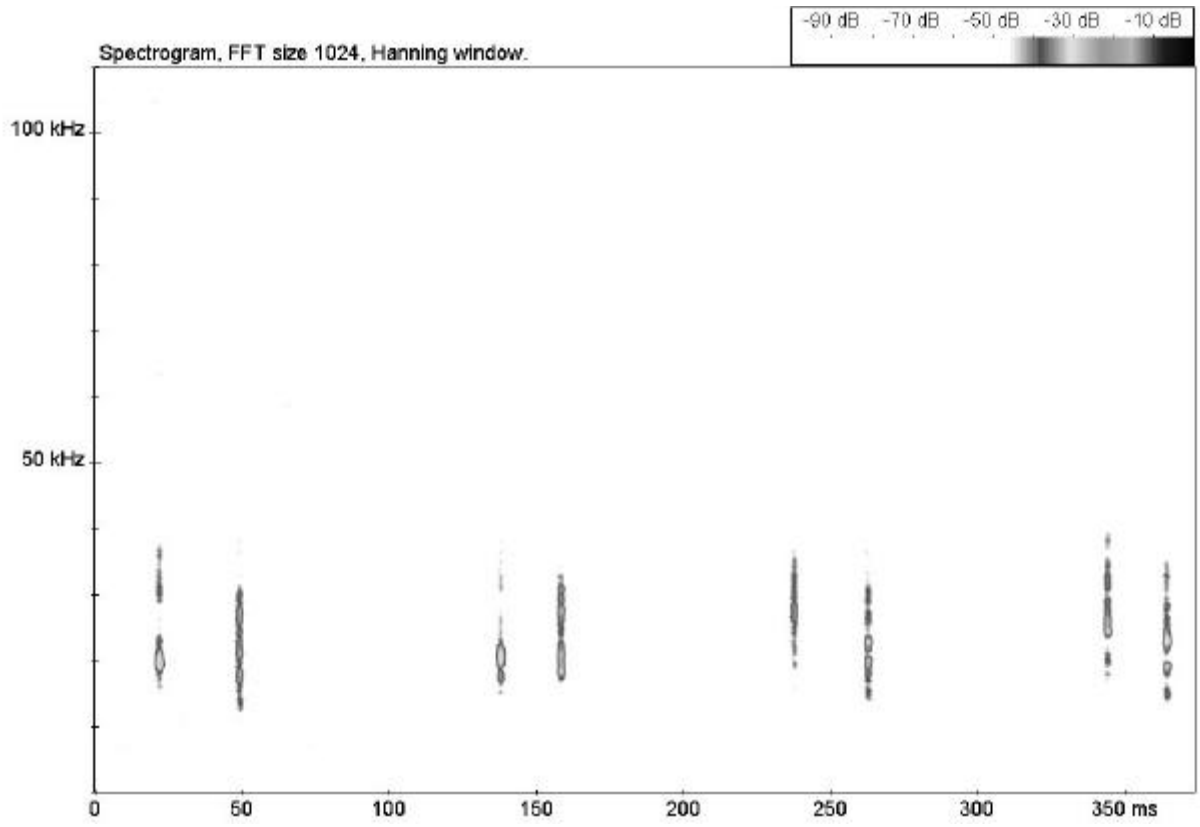
Suborder: MEGACHIROPTERA	
Family: PTEROPOPIDAE	**EN: Madagascar Rousette**
Genus: *ROUSETTUS*	**FR: Roussette de Madagascar**

Figure 11, *Rousettus madagascariensis*, Ambodiadabo.

There are only 10 species belonging to the *Rousettus* genus in the world. The endemic Malagasy example has a long dense pelage, although less so on the neck, throat and shoulders. The upper parts are greyish-brown with some reddish-brown hues, while the underpants are paler grey-brown. The muzzle is rather pointed and the ears are relatively short. It has a relatively small body and the forearm is short. The wings are relatively narrow (metacarpals and phalanges short). Its size overlaps with the larger microchiropterans, from which it may also be distinguished by its darting flight and reflective tapetum

Characteristics	**Measurements**
Weight	35-84
Total length	110-130
Tail length	7-20
Foot	17-20
Ear	15-19
Wingspan	427-451
Tibia	22-36
Forearm	58-78
5th Metacarpal	42-48
Skull length	35-38
Condylobasal length	33-37

Echolocation: *Rousettus* bats are the only megachiropteran bats to have evolved echolocation. The system is very basic, consisting of a series of clicks made with the tongue, which enable the bat to gain low definition information about its surroundings. Although these calls are not particularly quiet, they are very difficult to identify in the field and separate from the background noise. Calls are usually produced in pairs, about 30ms apart, the two calls being produced at about 115ms intervals.



Sonogram 1. Echolocation calls of *Rousettus madagascariensis*.

Emballonura atrata (Peters, 1874)

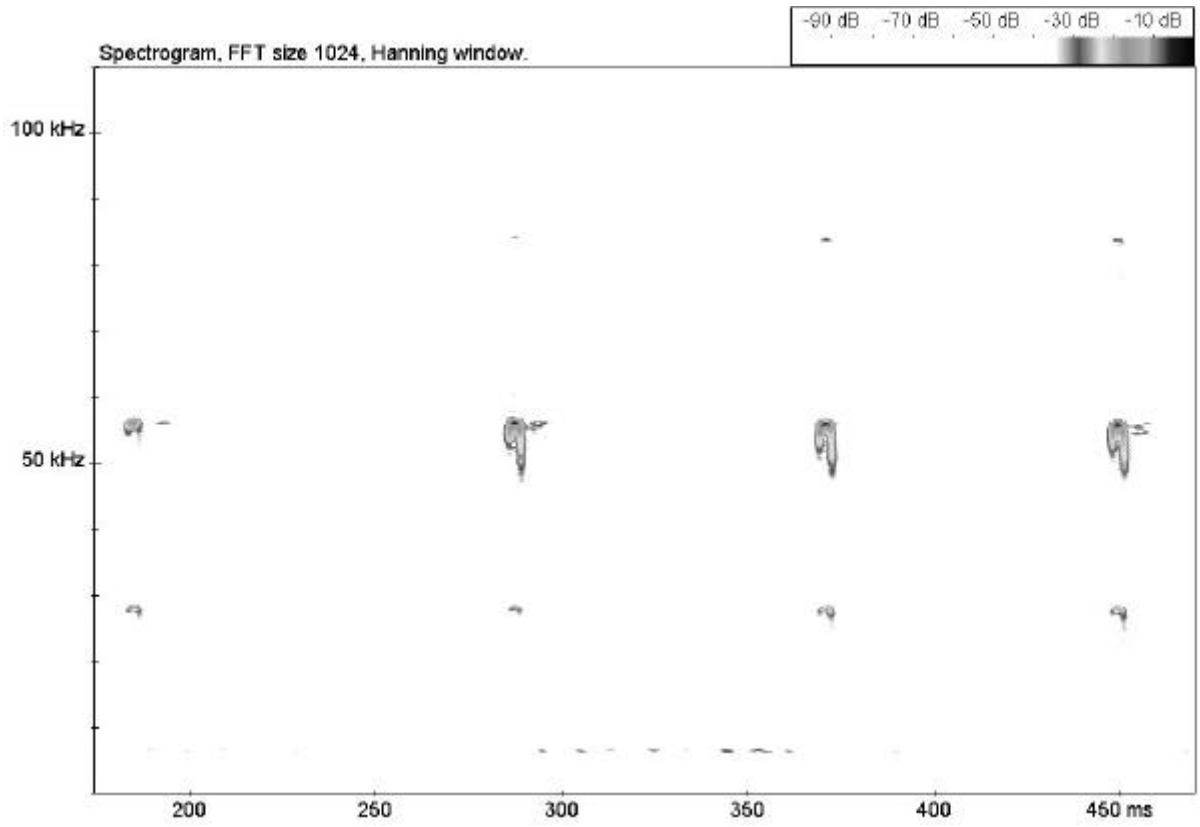
Suborder: MICROCHIROPTERA
Family: EMBALLONURIDAE **EN: Madagascar sheath-tailed bat**
Genus: *EMBALLONURA* **FR: Chauve-Souris malgache à queue en fourreau**

Figure 12. Emballonura atrata, Ambodiadabo and Nosy Mangabe.

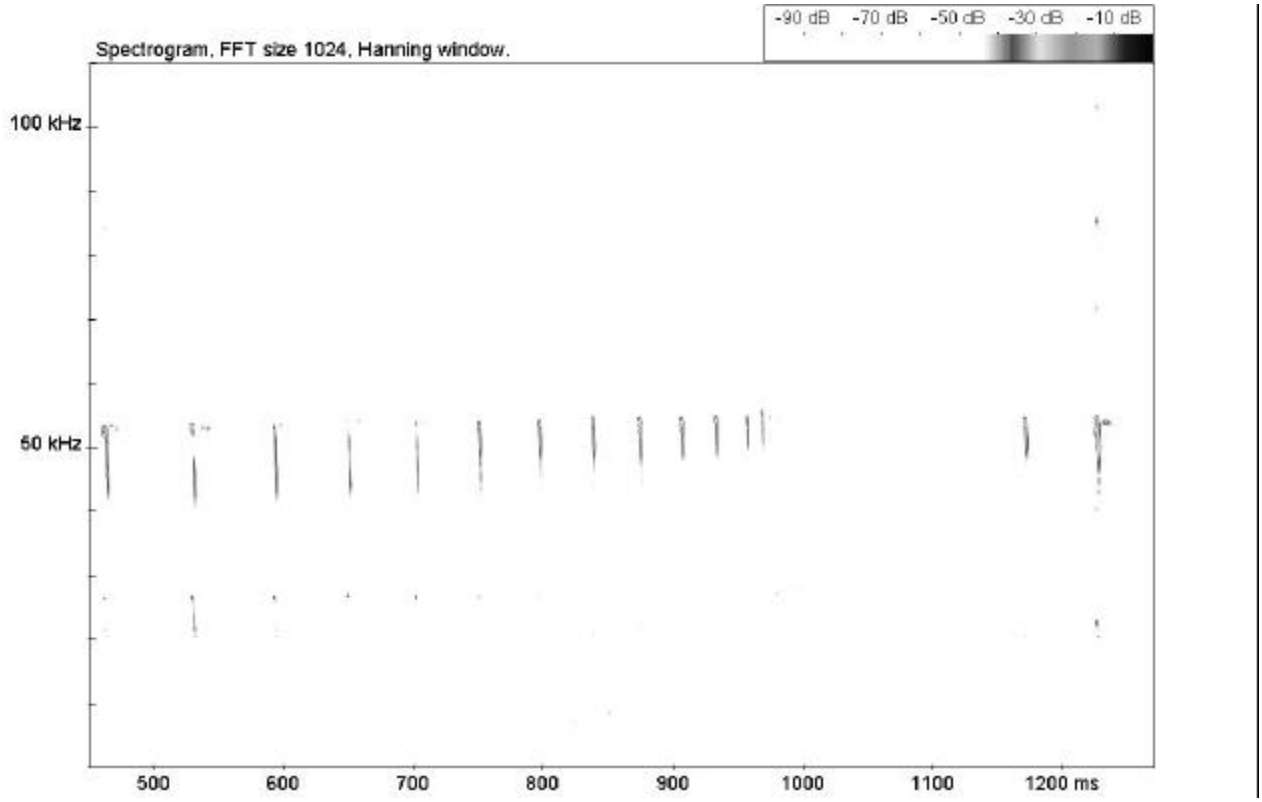
Emballonura atrata is endemic to Madagascar. The species has an overall blackish colouration and the body is small. Wing sacs are not present. The tail pierces the tail membrane, and its tip appears completely free on the upper surface of the membrane. The nasal appendages are poorly developed and the snout is quite pointed. The ears are prominent, broad and rounded, with a distinct 'notch' near their tip. When at rest, the wing tip is folded back on to the wing. This feature is often confused with that of the *Miniopterus* species, which have a more pronounced 'bent wing'. The species is widespread in Madagascar although its distribution is largely undocumented. It is listed as vulnerable by IUCN (Hutson *et al*. 2001).

Characteristics	**Measurements**
Weight	3.5-5.0
Total length	50-60
Tail length	14-21
Foot	6-8
Ear	13-15
Tibia	15-18
Forearm	35-41
5th Metacarpal	27-30
Skull length	13-14
Condylobasal length	11-12

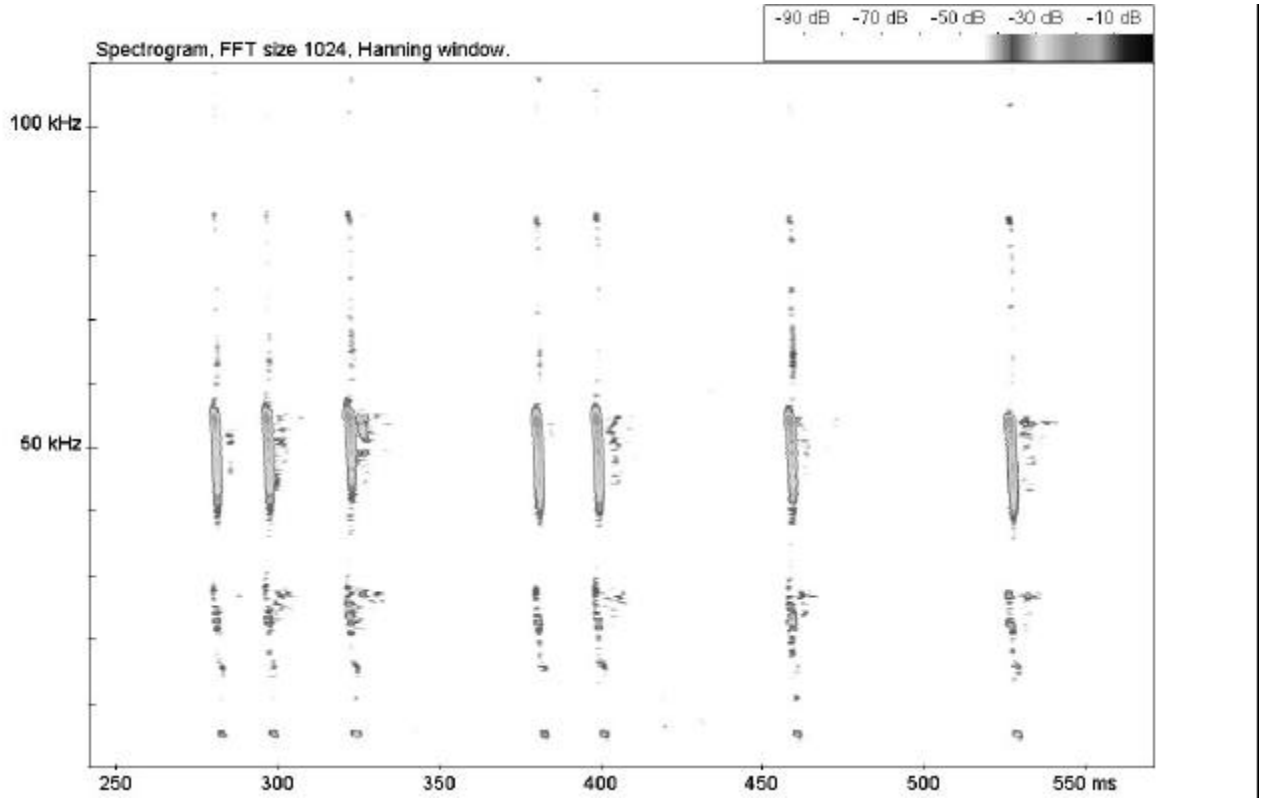
Echolocation: *Emballonura atrata* is regularly observed foraging at forest edges and over rivers at a height of 2-8 m. The species produces echolocation calls whose structure resembles that of the Hipposiderid bats echolocation, in that CF pulses are emitted which begin and terminate with a short FM sweep. In *E. atrata*, the CF portion is at about 55 kHz. The echolocation calls are of medium intensity and of about 7.3ms in duration. Within closed environments, such as in dense forest, the species emits rapid, short FM sweeps in quick succession which are particularly pronounced during insect capture. Within these sweeps the maximum energy is always concentrated around 55 kHz. While held in the hand, *E. atrata* emits high intensity distress calls. This call consists of a series of rapid and short FM sweeps with centre frequency at about 50 kHz. This series of sweeps are emitted intermittently.



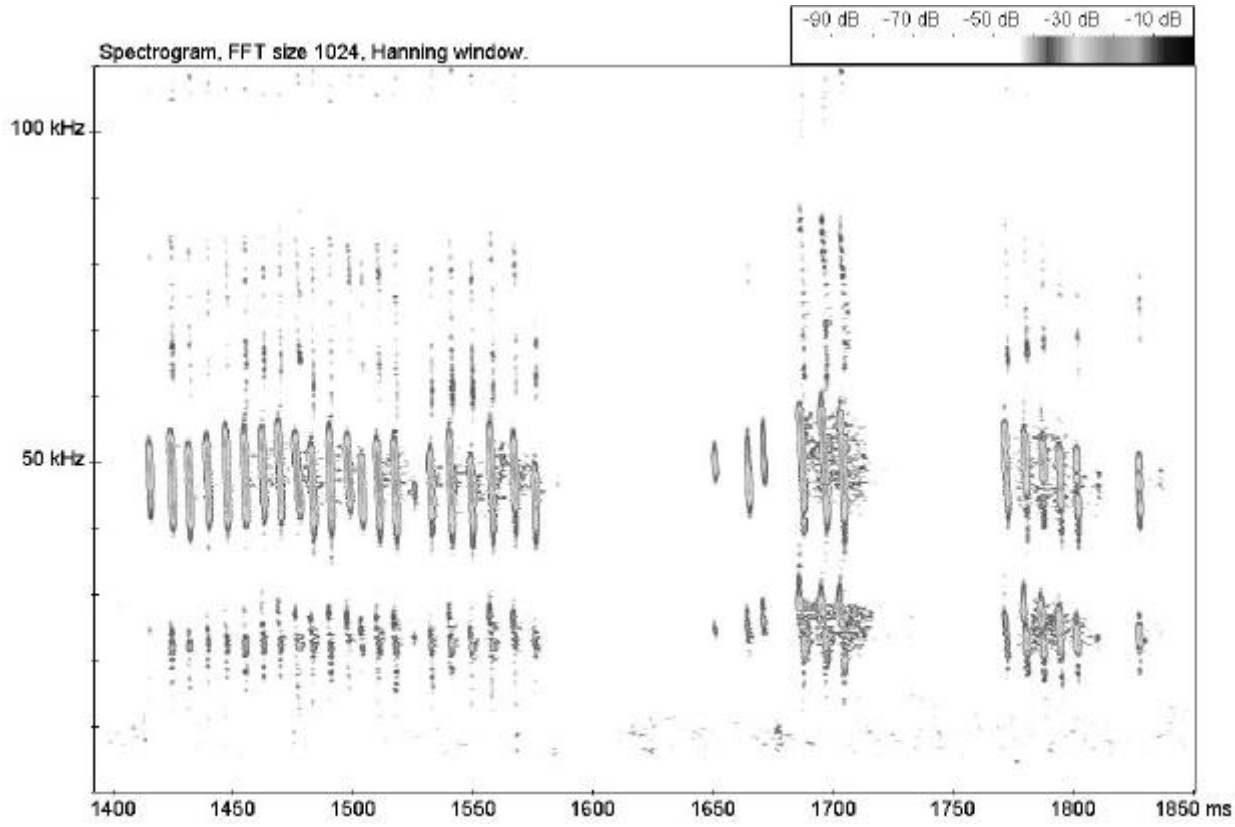
Sonogram 2. Echolocation calls of *Emballonura atrata* foraging in a relatively uncluttered environment.



Sonogram 3. Echolocation calls of *Emballonura atrata* showing the change in echolocation before, during, and after insect capture.



Sonogram 4. Echolocation calls of *Emballonura atrata* foraging in a relatively cluttered environment.



Sonogram 5. Distress calls of *Emballonura atrata* held in the hand.

Taphozous mauritianus (Geoffroy, 1818)

Suborder: MICROCHIROPTERA	
Family: EMBALLONURIDAE	**EN: Mauritian tomb bat**
Genus: *TAPHOZOUS*	**FR: Chauve-Souris mauritienne des tombeaux**

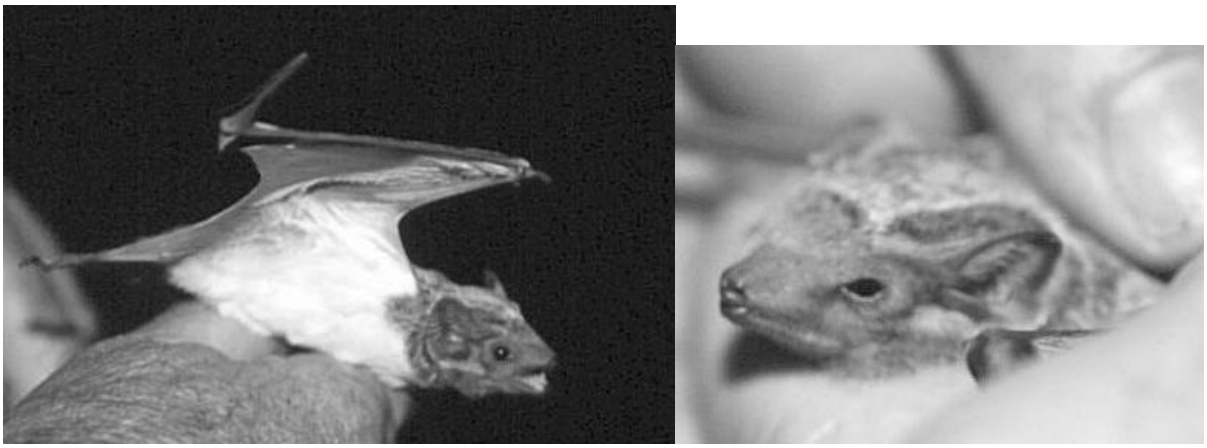
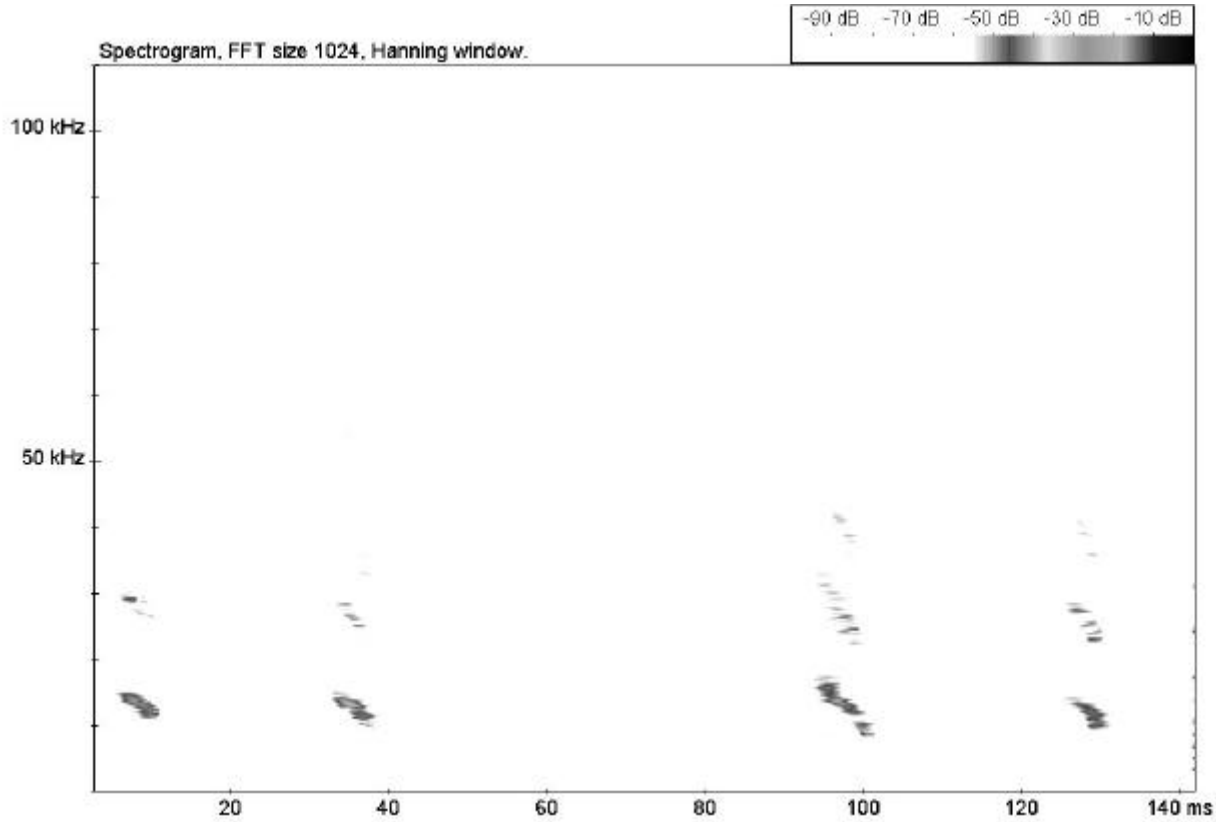


Figure 13. *Taphazous* courtesy of Peter Taylor, Durban bat group.

The tail is as for *Emballonura*, and the family in general. The coat comes together on the back and is markedly greyish/ dull. Everything on the ventral surface is grey to creamy white. Individual hairs are pale brown with white tips. Juveniles are generally a darker grey-brown than the adults. Males have a large glandular sac in the lower throat. The head is quite flattish and triangular, and the face below and in front of the eyes is bare. Two lower incisors are present and the second premolar (P2) is very large. We have not encountered this species in Madagascar. It is known from the east and the southwest of the island. The species is not considered threatened by IUCN (Hutson *et al*. 2001).

Characteristics	**Measurements**
Tibia	27-28
Forearm	61-64
5th Metacarpal	37-38
Mass	20-36

Echolocation: Produces low frequency calls, of medium intensity. A number of harmonics can be present. The loudest frequency is at 13kHz.



Sonogram 6. Echolocation calls of *Taphozous mauritianus* (Calls recorded from a South African specimen, P. Taylor).

Nycteris madagascarensis (Grandidier, 1937)

Suborder: MICROCHIROPTERA	
Family: NYCTERIDAE	**EN: Madagascar slit-faced bat**
Genus: *NYCTERIS*	**FR: La Chauve-souris malgache balafrée**

Figure 14 *Nycteris* from Africa courtesy of Peter Taylor, Durban bat group

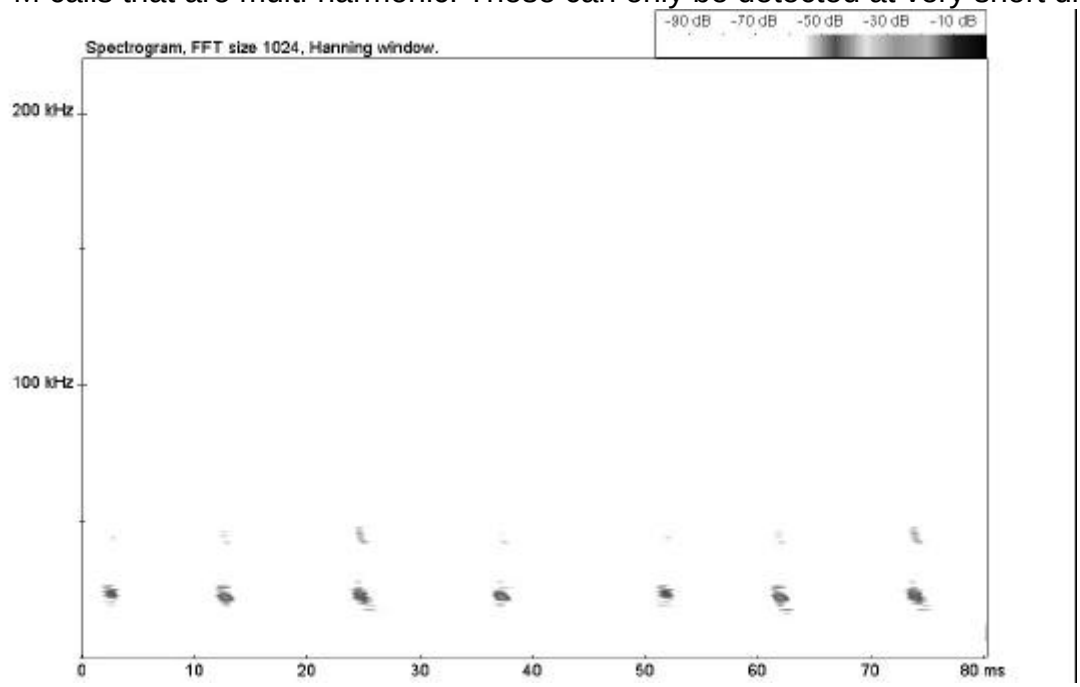
Figure 15 *Nycteris*, Bui National Park, Ghana, showing T-shaped tail tip

Only two examples have been recorded from Madagascar, both collected in 1910 from Irodo north of Ankarana. *N. madagascariencis* is sometimes considered a full species and sometimes a synonym of *N. thebaica*, but Van Cakenberghe and De Vree (1985)

indicate that it is a synonym of *N. macrotis*. However, it is generally now accepted that it is a distinct (endemic) species. *N. madagascariensis* has an average sized body and long ears, which are united at their bases by a low membrane. The coat is light greyish-brown on the back and light slate-grey on the stomach. The muzzle is divided by a longitudinal furrow, with the nostrils in the anterior end of this groove. This furrow is margined and concealed by nose leaves and expands posteriorly into a deep pit on the forehead. The lower lip has a granular surface at the tip. A small tragus is present. The wings are broad. The long tail is completely enclosed within the large interfemoral membrane and terminates in a T–shaped tip, which serves as support for the free edge of the tail membrane. This is unique among mammals. The upper incisors closely resemble the lower incisors in shape and form. The bifurcation at the tip of a long tail forming a Y-shape, is also typical of this species. The species is listed as data deficient by IUCN (Hutson *et al*. 2001).

Characteristics (from 1 individual)	**Measurements**
Total length	115
Tail length	55
Foot	14
Ear	28
Tibia	25
Forearm	51
5th Metacarpal	45
Length of Skull	22
Condylobasal length	19

Echolocation: The echolocation calls of *N. madagascariensis* have not been recorded. However, it is likely that they are similar in structure to those of *N. thebaica* from South Africa which produces low intensity, short duration calls which are broadband, steep FM calls that are multi-harmonic. These can only be detected at very short distances.



Sonogram 7. Echolocation of *Nycteris* from Africa, composite based on Taylor (2000)

Hipposideros commersoni commersoni (Geoffroy, 1813)

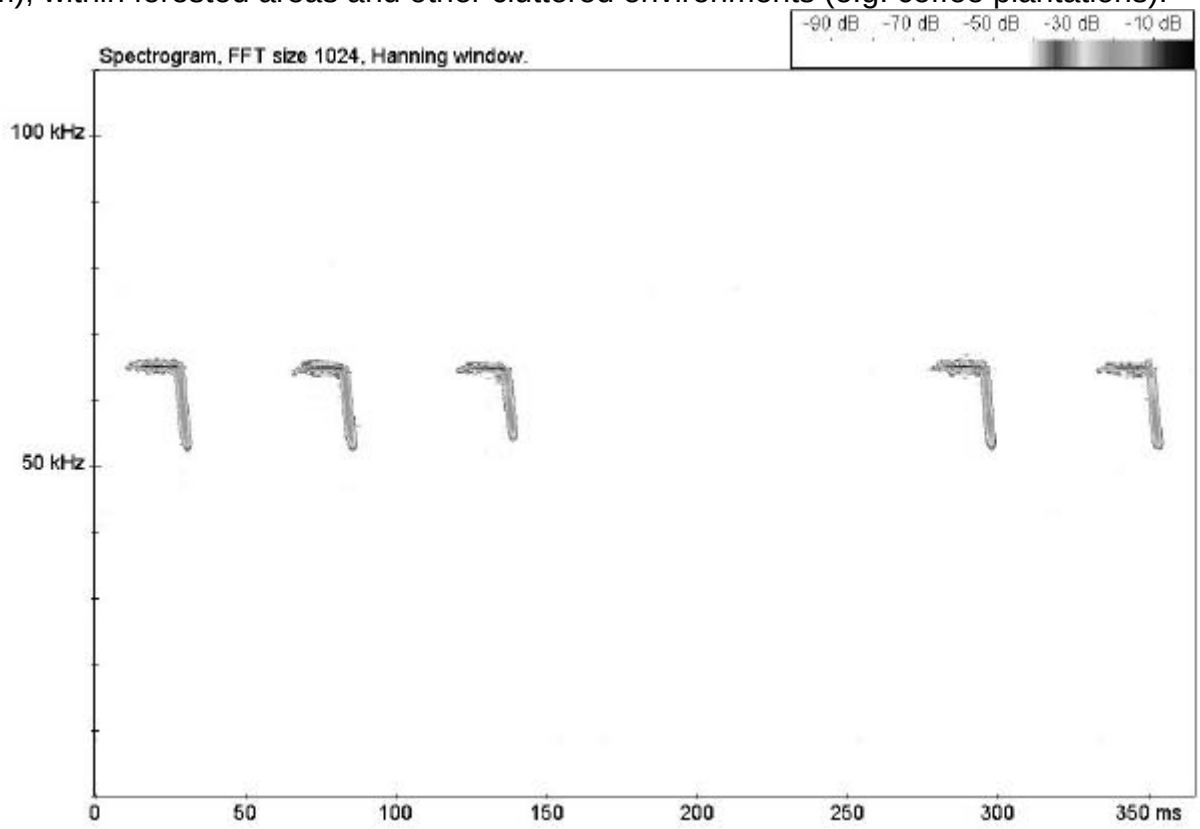
Suborder: MICROCHIROPTERA
Family: HIPPOSIDERIDAE **EN: Commerson's leaf-nosed bat**
Genus: *HIPPOSIDEROS* **FR: La Chauve-Souris de Commerson à nez feuillu**

Figure 17. *Hipposideros commersoni*, Nosy Mangabe

The species has a very large body and triangular ears that are narrow at the base, but pointed at the tip with a concave posterior edge. The upperparts and head are pale grey-brown to reddish-brown, while the underparts are pale tawny with white flanks. The nose-leaf is large and elaborate. Females are smaller than males. Males have a well-developed frontal gland above the noseleaf, which is absent or poorly defined in females and non-breeding males. The species is widespread in Madagascar and not considered threatened by IUCN (Hutson *et al*. 2001).

Characteristics	**Measurements**
Mass	36-68
Total length	110-140
Tail length	23-32
Foot	17-28
Ear	20-28
Tibia	34-39
Wingspan	530-561
Forearm	80-97
5th Metacarpal	57-69
Wingspan	540-560
Skull length	29-33
Condylobasal length	26-29

Echolocation: *Hipposideros commersoni* produces long CF echolocation calls that begin and terminate with a short FM portion. Occasionally, when the bat is close to an object, for example insect prey, the terminal FM sweep was more broadband. The frequency of the CF portion is around 64 kHz and the duration of the call is approximately 20 ms. The first harmonic is dominant, but the fundamental can occasionally be seen at around 62kHz (maximum energy). The echolocation calls are of medium intensity and the inter-pulse interval is about 62ms. This species is often observed perching on the branches of trees, often within 1.5 m of the ground, moving its head from side to side, during which, echolocation calls are emitted, which increase in rate as the observer approaches. It is likely that during this time the bat is searching for prey. While hunting, *H. commersoni*, often flies very close to the ground (around 1 m), within forested areas and other cluttered environments (e.g. coffee plantations).



Sonogram 8. Echolocation calls of *Hipposideros commersoni* in a relatively cluttered environment

Triaenops furculus (Trouessart, 1906)

Suborder: MICROCHIROPTERA	
Family: HIPPOSIDERIDAE	**EN: Trouessart's trident bat**
Genus: *TRIAENOPS*	**FR:**

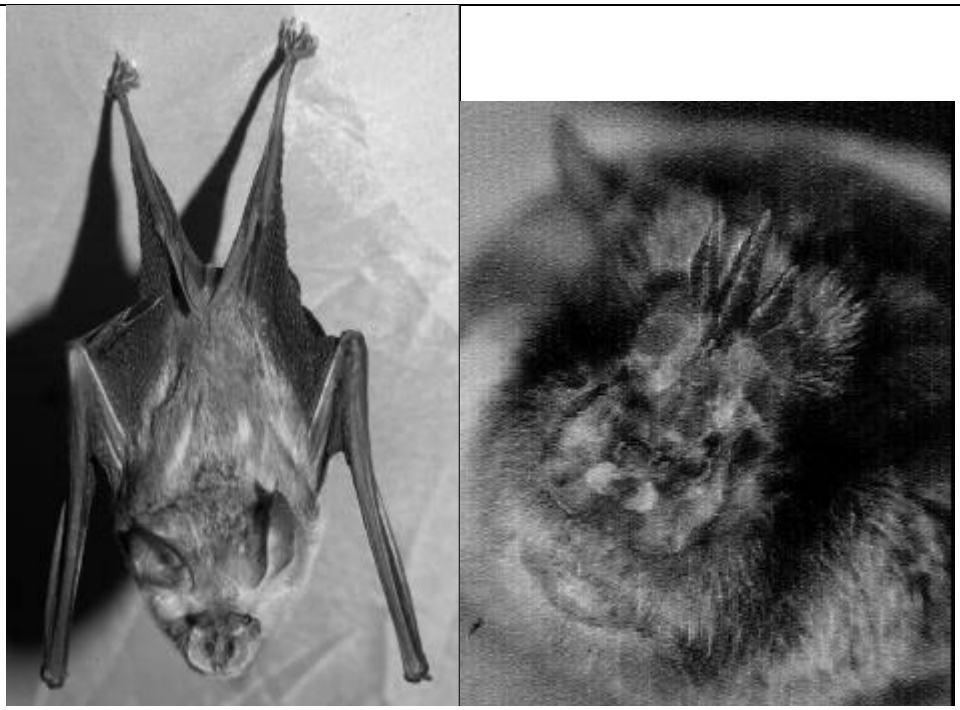


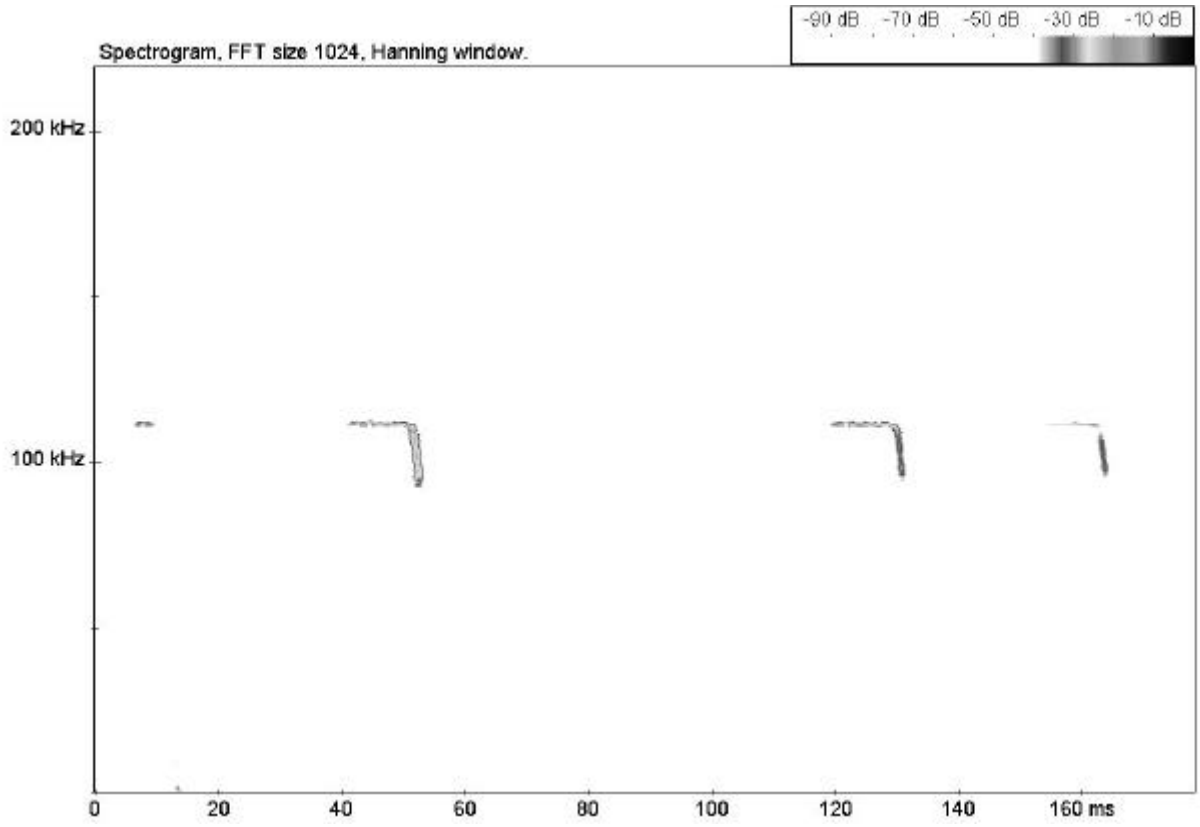
Figure 18. *Triaenops furculus*, St Augustin.

The species is endemic to Madagascar and is relatively small, and has large ears which are pointed at the tip and are indented on the internal face. There is a lateral split of the cone-shaped nose-leaf. The pelage is grey-brown on the upper surface and light grey on the underside. The nose leaf has a three pronged trident. The lobes of the 'trident' are more or less of the same shape. Known only from caves in the west of Madagascar. The species is not considered vulnerable by IUCN (Hutson *et al*. 2001).

Characteristics	Measurements
Mass	5-9.5
Total length	61-72

Tail length	20-25
Foot	8-9
Ear (from the notch)	15-19
Tibia	17-19
Wingspan	268-281
Forearm	43-47
5th Metacarpal	27-31
3rd Metacarpal	31.5-34.5
Skull length	17.6-18.2
Condylobasal length	15.5-16.2

Echolocation: Bats produce echolocation calls with a relatively long CF portion, often followed by an FM sweep. The frequency of the CF portion is at about 112kHz and the inter-pulse interval is about 44ms. The first harmonic is dominant, but the fundamental is occasionally apparent at around 56kHz (maximum energy). In cluttered situations, the call becomes shorter in duration, and the FM sweep becomes more broadband. The FM sweep may not appear in open situations.



Sonogram 9. Echolocation calls of *Triaenops furculus*.

Triaenops auritus (Grandidier, ?)

Suborder: MICROCHIROPTERA	
Family: HIPPOSIDERIDAE	**EN: Trouessart's trident bat**
Genus: *TRIAENOPS*	**FR:**

Allen (1939) considered *T.auritus* synonymous with *T. furculus*, as do many authors. Petterson et al. (1995) suggest that based on external measurements of a single specimen it is distinct from *T. furculus*. Based on these measurements, the external characteristics resemble that of *T. furculus*, but the feet and tail are shorter, the tibia is slightly longer, the forearm length may be longer but the metacarpals are markedly longer (especially the 3rd). The dorsal pelage is grey-black, whitish at the base and black at the tips especially lower dorsum and the ventral pelage is lighter, or dirty grey. The nose leaf has a three pronged trident. Only one specimen of this bat is known, described by Grandidier in 1912 from near Diego Suarez in the far north. The species is listed as data deficient by IUCN (Hutson *et al*. 2001).

Characteristics (based on a single specimen)	**Measurements**
Mass	-
Total length	65
Tail length	15?
Foot	7?
Ear (from the notch)	16?
Tibia	19
Wingspan	-
Forearm	45
5th Metacarpal	31
3rd Metacarpal	37
Skull length	-
Condylobasal length	-

Echolocation: Unrecorded

Triaenops rufus (Milne-Edwards, 1881)

Suborder: MICROCHIROPTERA	
Family: HIPPOSIDERIDAE	**EN: Rufous trident bat**
Genus: *TRIAENOPS*	**FR:**

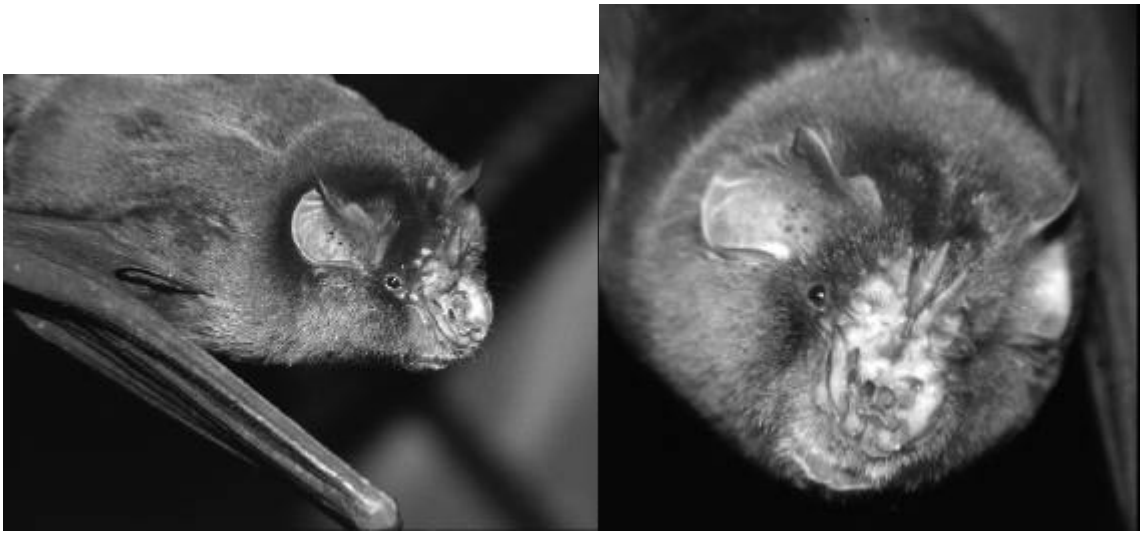


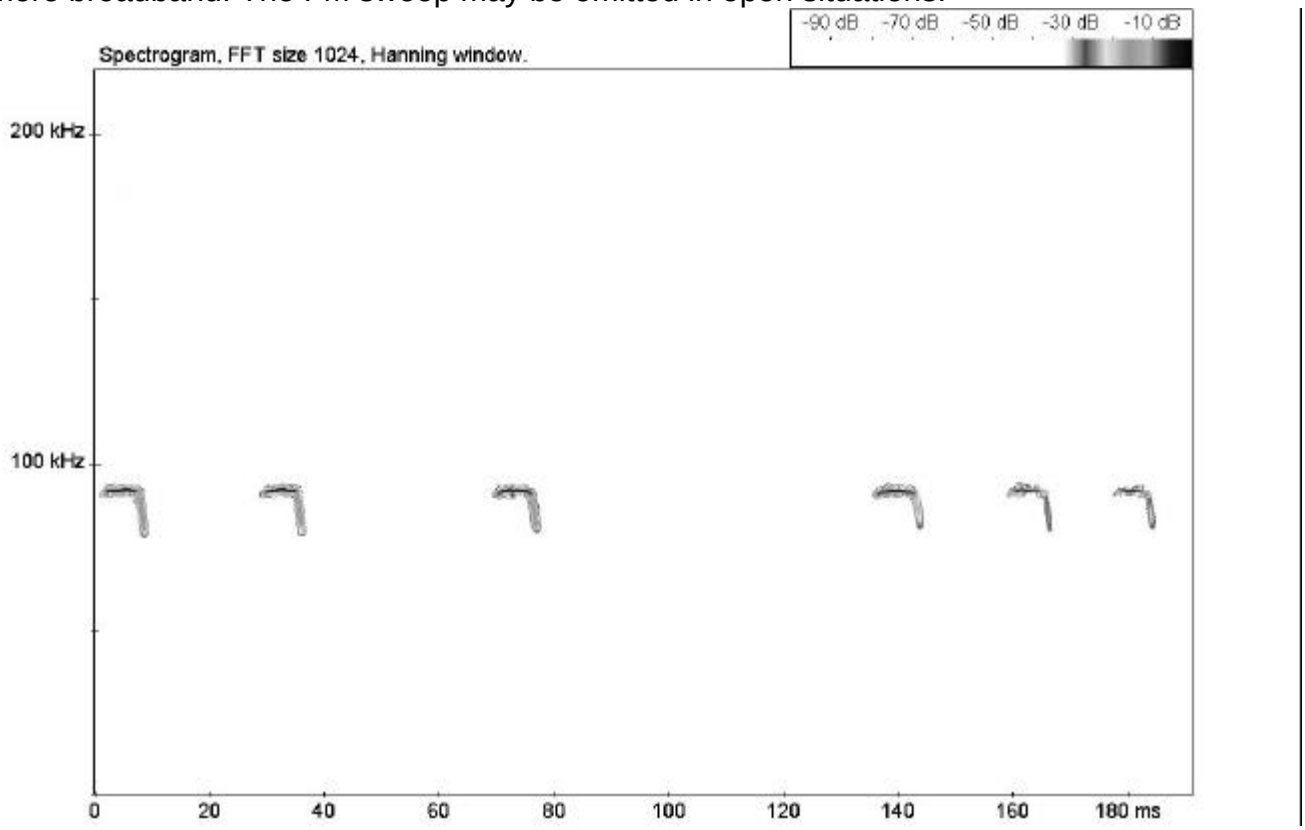
Figure 19. *Triaenops rufus*, Ambodiadabo

A medium sized species, with relatively small ears deeply cut at the internal edge with a right angle. The pelage is variable, from reddish-brown to greyish-beige. The nose leaf has a three pronged trident. This species is found throughout Madagascar, although its distribution is patchy and it appears to be a rarer member of communities. The quiet calls of *Triaenops* make them difficult to detect in the field. We have found this bat in caves around St Augustin together with *T. furculus* and *Miniopterus manavi* and in Ambodiadabo sharing flyways with *Rousettus* and *Myzopoda.* The species is listed as data deficient by IUCN (Hutson *et al*. 2001).

Characteristics	**Measurements**
Mass	8-9.5
Total length	85-90
Tail length	31-44
Foot	9-11
Ear	10-14
Tibia	17-20
Forearm	52-56
5th Metacarpal	28-33
Skull length	19-21
Condylobasal length	17.5-18.5

Echolocation: Echolocation: Bats produce echolocation calls with a relatively long CF portion, often followed by an FM sweep. The frequency of the CF portion is at about 91kHz and the inter-pulse interval is about 60ms. The first harmonic is dominant, but the fundamental can occasionally be seen at around 45kHz (maximum energy). In

cluttered situations, the call becomes shorter in duration, and the FM sweep becomes more broadband. The FM sweep may be omitted in open situations.



Sonogram 10. Echolocation calls of *Triaenops rufus*.

Myotis goudoti goudoti (Smith, 1834)

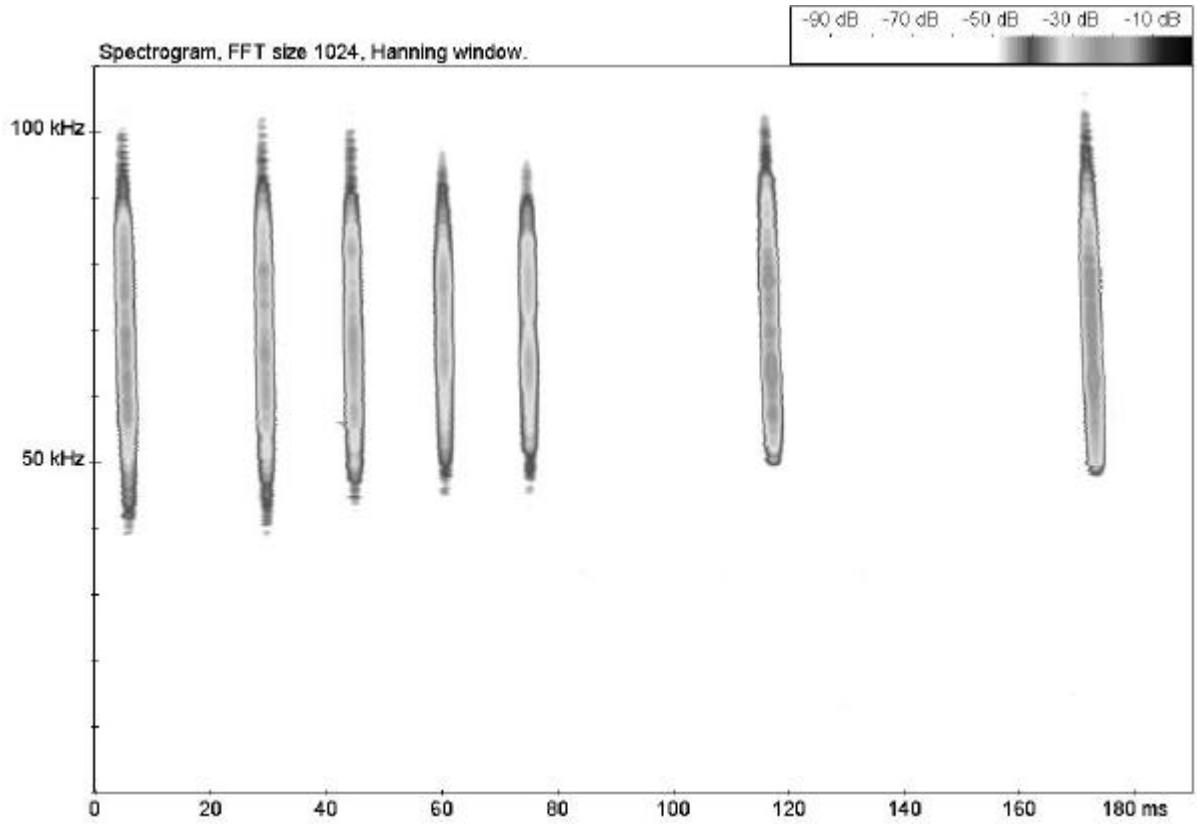
Suborder: MICROCHIROPTERA	
Family: VESPERTILIONIDAE	**EN: Malagasy mouse-eared bat**
Genus: *MYOTIS*	**FR: Chauve-Souris malgache à orielle de souris**

Figure 20. *Myotis goudoti.* Andasibe.

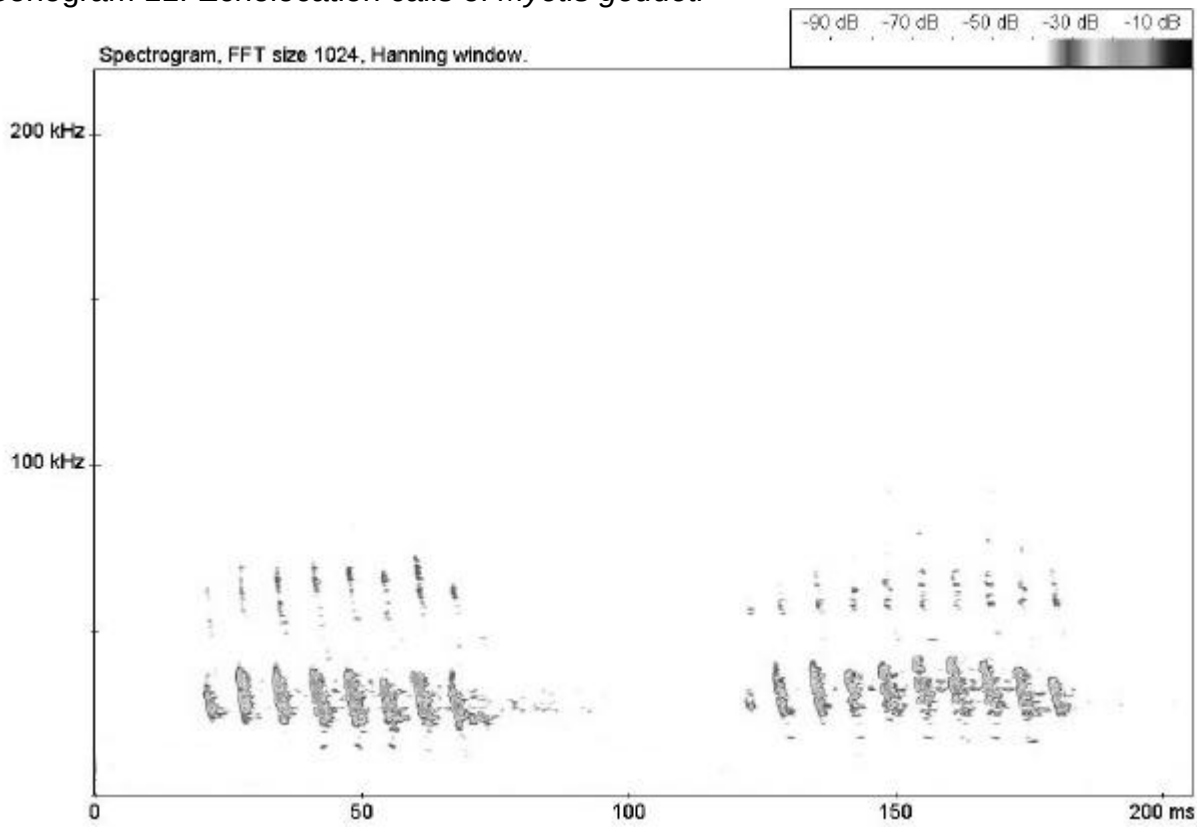
Myotis goudoti goudoti is endemic to Madagascar. The ears are longer than average. The spur is relatively long (17 to 18 mm), without a distinct hull. The tragus reaches just beyond the middle of the ear. The pelage is soft and thick and ginger in colour. The under parts are paler. There is no postcalcarial lobe. The head appears somewhat flattened and the muzzle is short. The species is widespread in Madagascar and not considered threatened by IUCN (Hutson *et al*. 2001)..

Characteristics	**Measurements**
Mass	5-6
Total length	84-90
Tail length	36-42
Foot	9-11
Ear	15-18
Tibia	16-19
Forearm	34-41
5th Metacarpal	34-37
Skull length	15.0-15.5
Condylobasal length	13.9-14.4

Echolocation: Calls from this species consist of a single frequency modulated sweep, sweeping down from about 75 kHz to about 55 kHz. The repetition rate is high. Its ultrasound is quite quiet, especially in cluttered situations, where the calls become very broadband, short in duration with a very high repetition rate. Distress calls consist of a series of FM sweeps of relatively high intensity.



Sonogram 11. Echolocation calls of *Myotis goudoti*



Sonogram 12.. Distress calls of *Myotis goudoti*

Pipistrellus/Eptesicus spp.

Suborder: MICROCHIROPTERA	
Family: VESPERTILIONIDAE	**EN:**
Genera: *PIPISTRELLUS and EPTESICUS*	**FR:**

The species that occur in Madagascar have yet to be accurately determined. Göpfort *et al*. (1995) suspected that tw, probably three different *Pipistrellus* species were represented in Madagascar). One species is closely related to *P. nanus*, but differs in its dentition and structure of the baculum. The second species appears to exhibit close links to the '*kuhlii*-group' of pipistrelles – its skull and bacular morphology are very similar to that of *P. kuhlii* from South Africa. The third taxon probably represents an undescribed species. On the basis of dentition and bacular morphology it show some resemblance to the '*pipistrellus*-group' of the genus, but appears to have its closest links with species in the oriental region. The ear is usually shorter and broader than *Myotis*, and the tragus is not sharply pointed. There is a postcalcarial lobe present. *Pipistrellus* bats in Madagascar are not considered threatened by IUCN (Hutson *et al*. 2001).

We have encountered three distinct species of *Eptesicus/Pipistrellus* in Madagascar which are described below, followed by a summary of the current taxonomy. This is necessary because we were unable to identify hand-held animals to species, nor are we aware of a suitable diagnostic feature that can distinguish between live members of the two genera.

Pipistrellus/Eptesicus sp. 1, from Antananarivo and Andasibe.

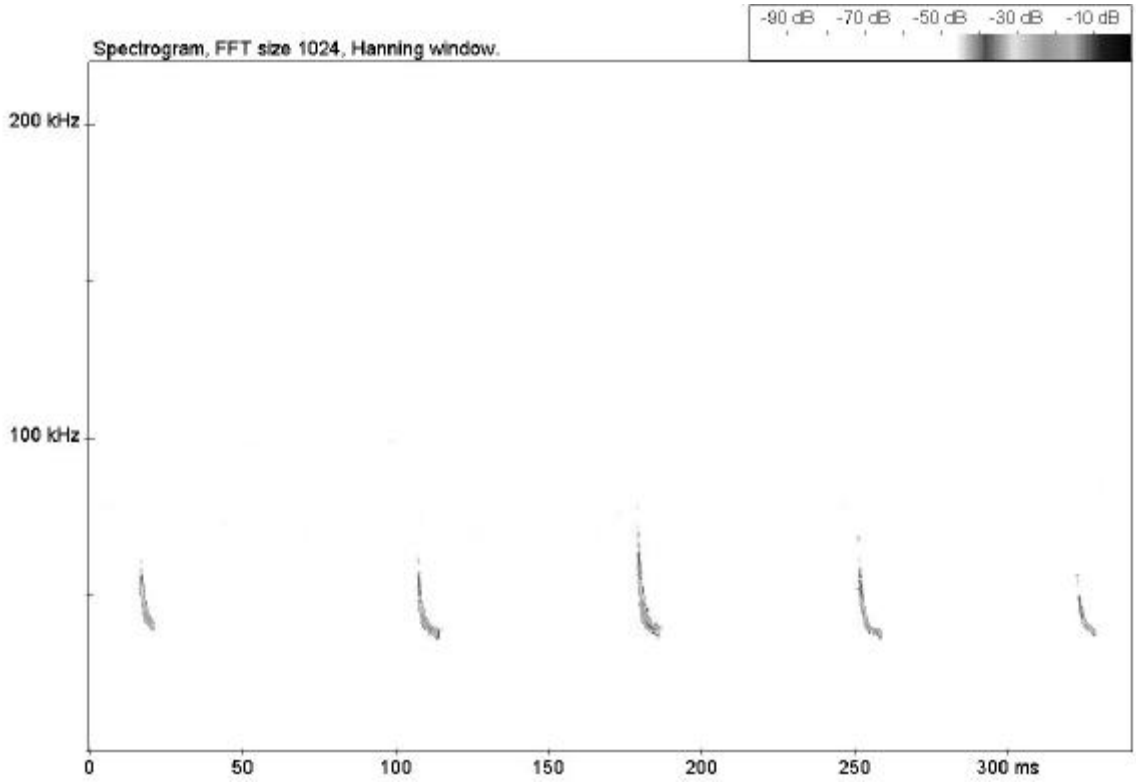
Suborder: MICROCHIROPTERA	
Family: VESPERTILIONIDAE	**EN:**
Genera: *PIPISTRELLUS and EPTESICUS*	**FR:**

Figure 21. Eptesicus/Pipistrellus species from Antananarivo

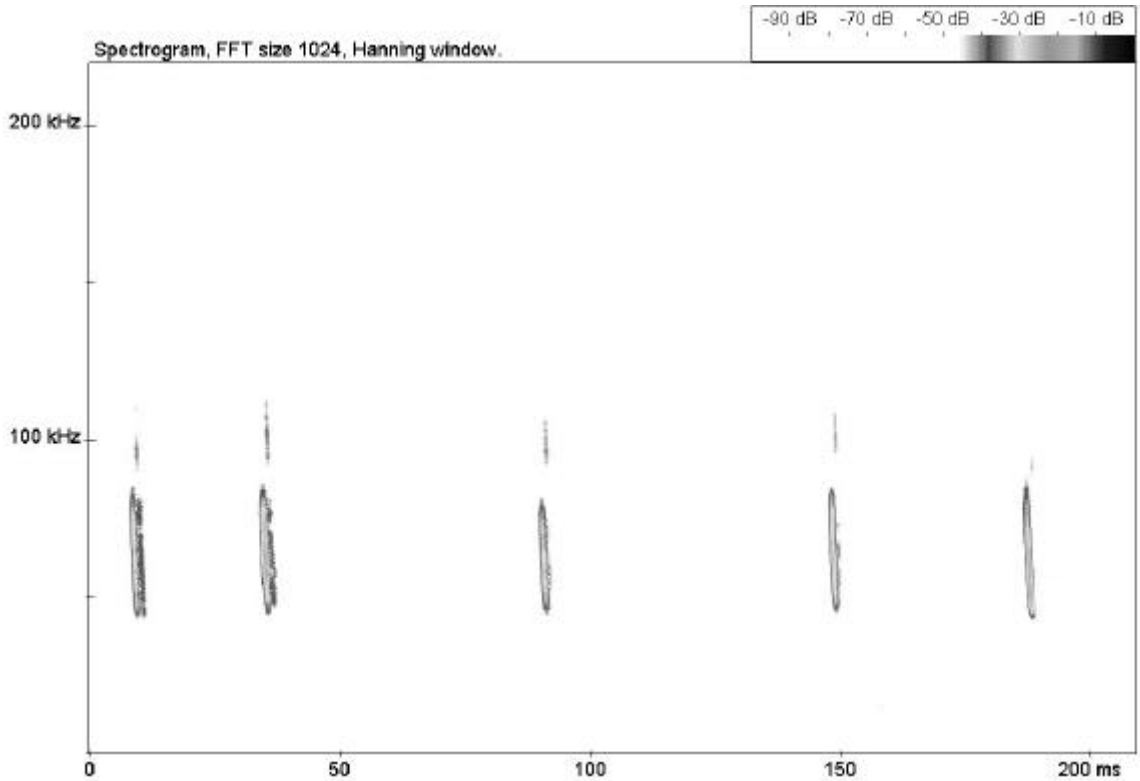
A small bat with a forearm of 30.9 - 34mm and a weight of 5-7g.

Measurements from one individual (male): Forearm 31.4mm; ear: 9.2mm; Wingspan:209mm;Total length:75.8mm;Tail:32.9mm;Tibia:12.9mm; 5DME:39.4mm incl. wrist; Tragus:5.2mm; 3D3P:27.1mm;upper tooth row I1,I2 present;P1 slightly shorter than canine; base canine dist:4.4mm; base incisor dist:1.9mm; canine less elongated than Andasibe specimen (see below).

Echolocation: Call consists of an FM sweep which terminates in a CF portion with maximum energy at around 40kHz. In cluttered situations, the call becomes more broadband and shorter in duration and the maximum energy may rise slightly. In open situations, the calls become less broadband, longer in duration and, occasionally, the FM sweep may be almost non-existent.



Sonogram 13. Echolocation calls of *Eptesicus/Pipistrellus* spp. recorded in Antananarivo.



Sonogram 14. Echolocation calls of *Pipistrellus* spp. recorded in Andasibe in a cluttered environment.

Pipistrellus/Eptesicus sp. 2, from Andasibe.

Suborder: MICROCHIROPTERA	
Family: VESPERTILIONIDAE	**EN:**
Genera: *PIPISTRELLUS and EPTESICUS*	**FR:**

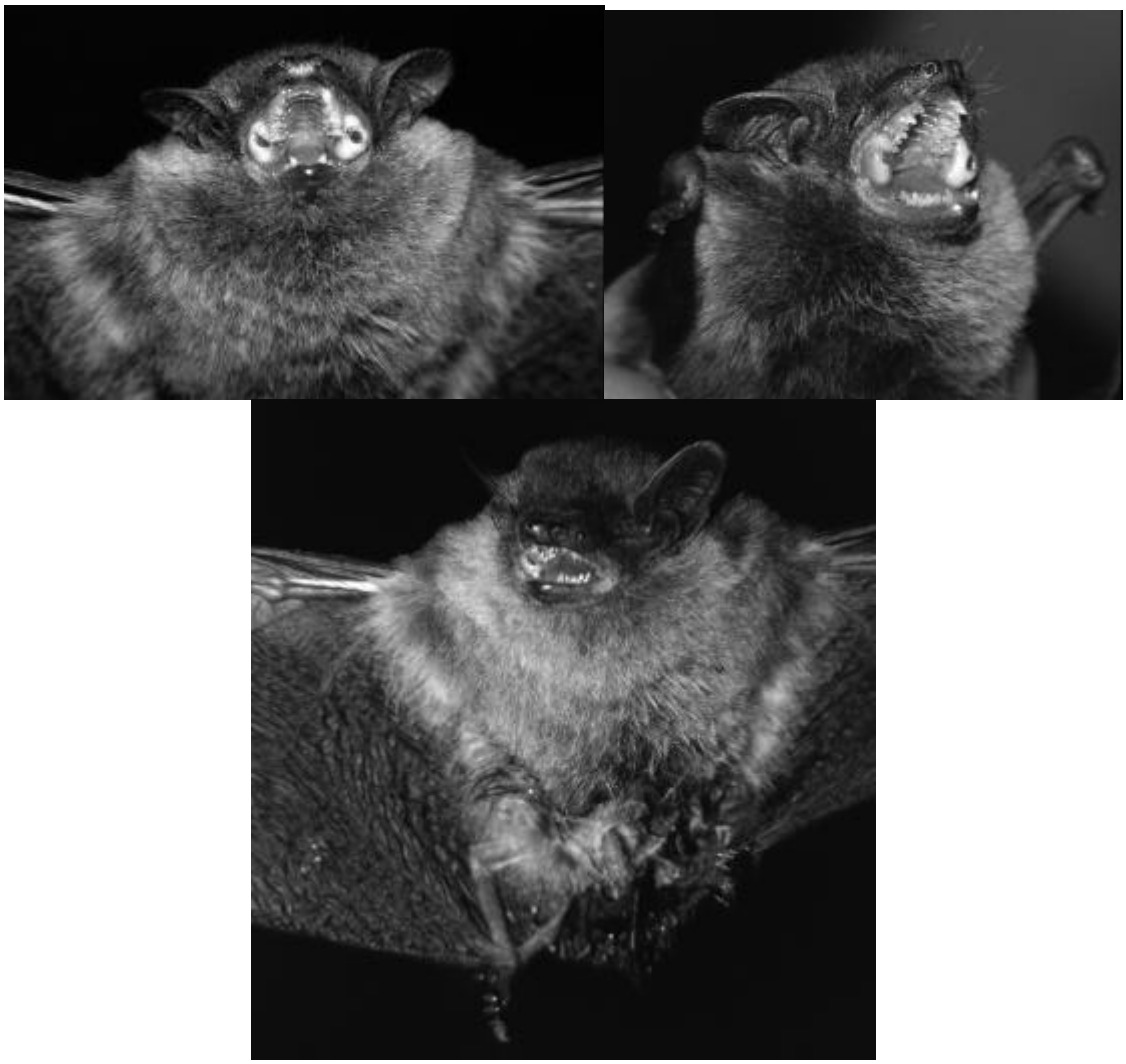
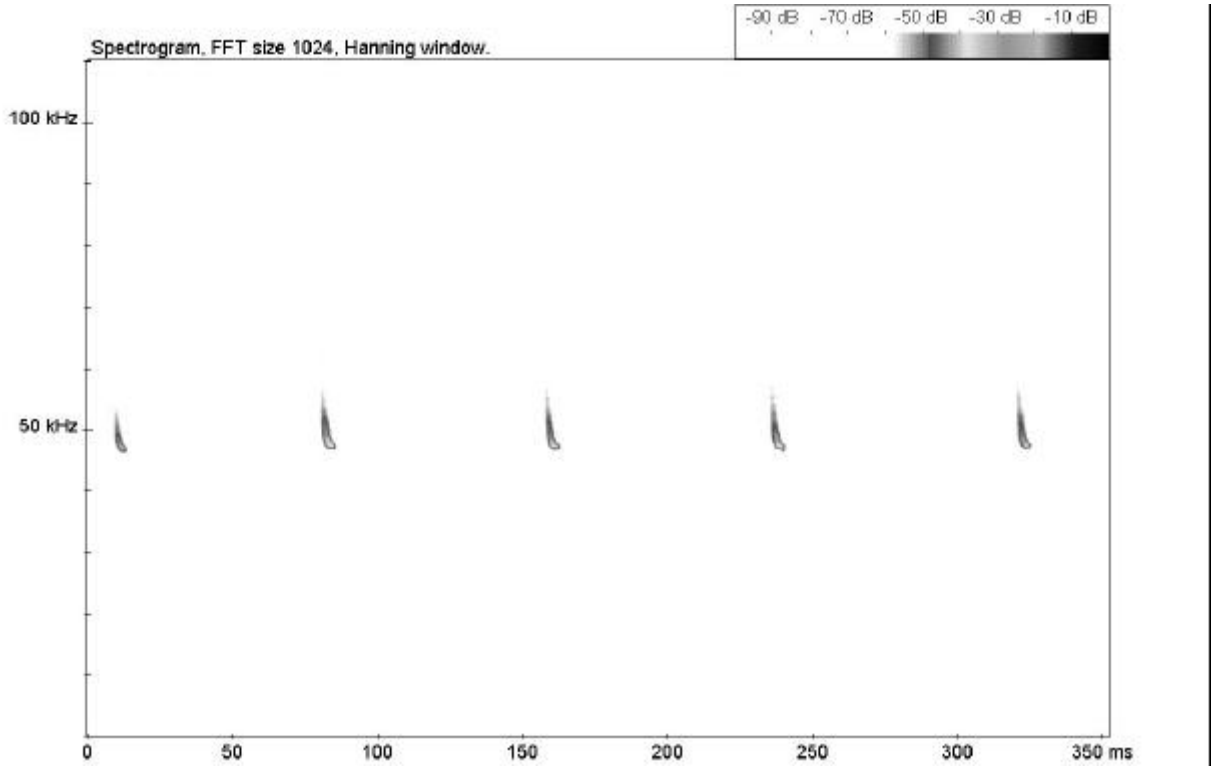


FIG 22. *Eptesicus/Pipistrellus,* Andasibe

Caught by an abandoned fish farm at Andasibe, a male bat weighing 6g with a forearm of 32.5mm. Tragus usually long (6mm), distinct calcareous lobe; Ear:13.9mm; Wingspan:227mm ;Total length inc tail:76.2;Tail from anus:31.9mm;Tibia:12.9;5 DME inc wrist 43;3D3P:28.6; Tragus:5.95;upper teeth row from M3-I1:5.65;I1pres I2 reduced;P1 1/2 height of canine;M1-M3 pres; base of canine dist:4.6;base of incisors dist:2.5;P3 absent). Very conspicuous glands in the corners of the mouth.



Sonogram 15. Echolocation calls of *Eptesicus/Pipistrellus species 2, Andasibe.*

Echolocation: Echolocation call consists of an FM sweep which terminates in a CF portion with maximum energy at around 46kHz. The duration is about 5ms and the inter-pulse interval is about 90ms. In cluttered situations, the call becomes more broadband and shorter in duration and the maximum energy may rise slightly. In open situations, the calls become less broadband, longer in duration and, occasionally, the FM sweep may be almost non-existent.

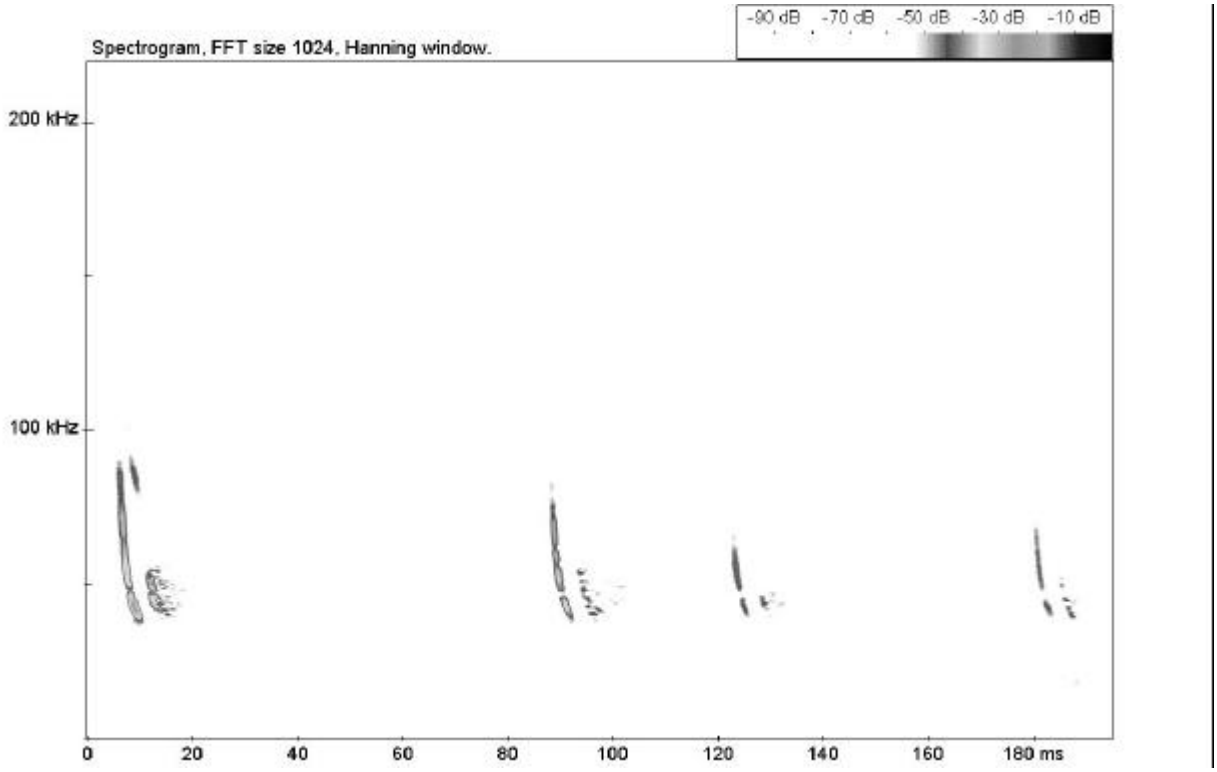
Pipistrellus/Eptesicus sp. 3, from St. Augustin.

Suborder: MICROCHIROPTERA
Family: VESPERTILIONIDAE **EN:**
Genera: *PIPISTRELLUS and EPTESICUS* **FR:**

Figure 23. Eptesicus/Pipistrellus species from St Augustin

A very small bat with a forearm of 28.5-30.8mm, and a weight of 3-4.5g.

Echolocation calls consist of an FM sweep which terminates in a CF portion with maximum energy at around 47kHz. In cluttered situations, the call becomes more broadband and shorter in duration and the maximum energy may rise slightly. In open situations, the calls become less broadband, longer in duration and, occasionally, the FM sweep may be almost non-existent.



Sonogram 16. Echolocation call of *Eptesicus/Pipistrellus* species 3, from St. Augustin.

Eptesicus somalicus malagasyensis (Thomas, 1901)

Suborder: MICROCHIROPTERA
Family: VESPERTILIONIDAE **EN: Somali serotine**
Genus: *EPTESICUS* **FR:**

The description of this endemic species is based on a single specimen. The dorsal fur is about 7mm long, is very dense, and sharply bicoloured: dark-brown at the base and brown tips, together with a uniform colour on the two sides. The ventral coat is dark and the top olive brown. The ears are translucent and medium brown. The tail is relatively short. The calcar has a strong hull. Compared to *E. matroka*, the head and the feet are much shorter; the coat on the dorsal side is much paler and more clearly two-coloured. The ears are paler and more translucent. The head is rounder and narrower. There is a postcalcarial lobe. The species is not considered threatened by IUCN (Hutson *et al*. 2001).

(based on a single specimen)

Characteristics	**Measurements**
Mass	9
Total length	84
Tail length	27
Foot	6
Ear	12
Wingspan	226
Tibia	12
Forearm	31.2
5th Metacarpal	30
Skull length	13.4
Condylobasal length	12.8

Echolocation: Unrecorded

Eptesicus matroka (Thomas & Schwann, 1905)

Suborder: MICROCHIROPTERA	
Family: VESPERTILIONIDAE	**EN: Madagascar serotine**
Genus: *EPTESICUS*	**FR:**

Eptesicus matroka is endemic to Madagascar. The species has very dark wings. The dorsal fur is brown. The underside is a pale muddy or waxy brown. The box-shaped cranium is more rounded and upper elongated than the other taxa. There is a postcalcarial lobe. Compared to *Eptesicus somalicus malagasyensis*, the head and feet are much larger. The species is listed as data deficient by IUCN (Hutson *et al*. 2001).

Characteristics	**Measurements**
Mass	4-9
Total length	74-90
Tail length	28-36
Foot	6-8
Ear	10-14
Wingspan	220-257
Tibia	11-14
Forearm	29-35
5th Metacarpal	26-32
Skull length	12.8-14.1
Condylobasal length	12.3-13.5

Scotophilus robustus (Milne-Edwards, 1881)

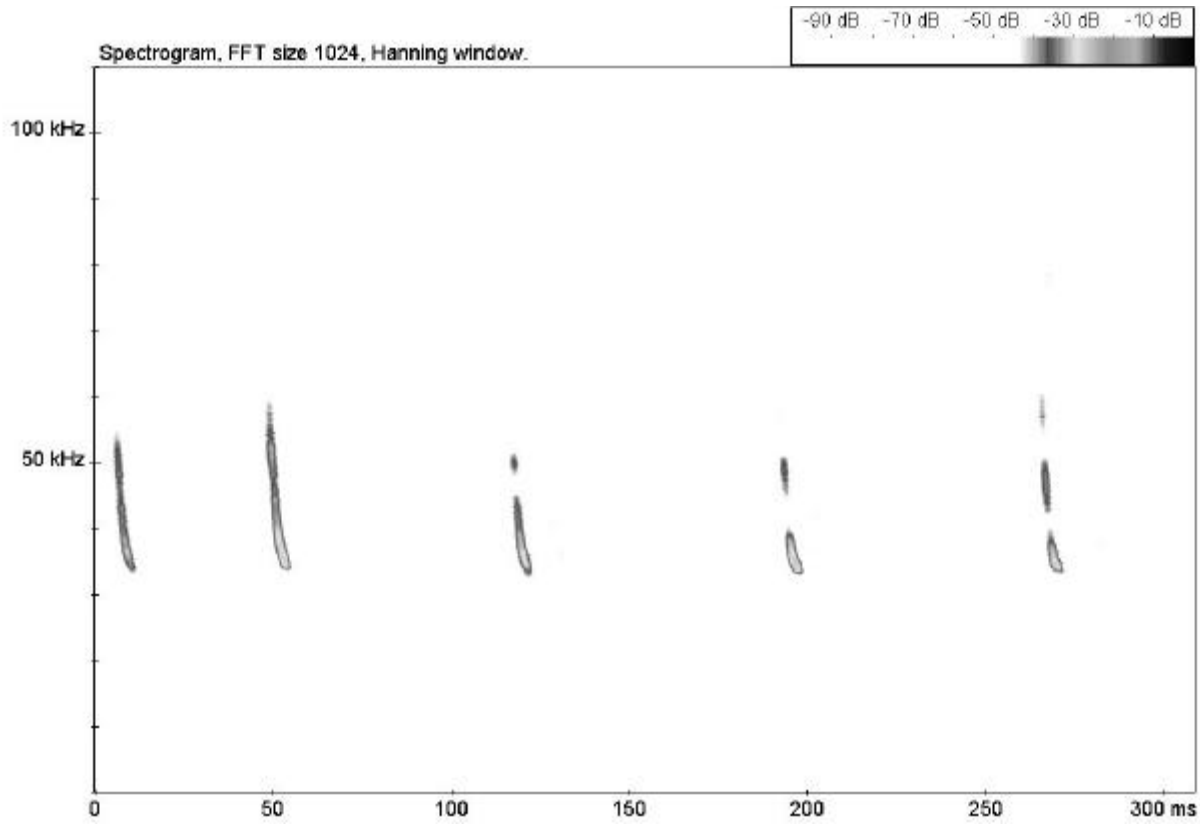
Suborder: MICROCHIROPTERA
Family: VESPERTILIONIDAE **EN:**
Genus: *SCOTOPHILUS* **FR: La Chauve-Souris domestique malgache**

Figure 24. *Scotophilus robustus*, Ambanizana.

S. robustus is endemic to Madagascar. The species has a large, heavy body with a robust head. It is mid-brown to yellowish-brown in colour, the underparts generally being paler. The jaws and teeth are powerful. There is a postcalcarial lobe present. Some authors have indicated that *S. borbonicus* is also present in Madagascar. Although this has not been confirmed and there is no specimen available to confirm the origin we have included it in the key. Hutcheon (1995) claimed to have caught S. *borbonicus* in northeastern Madagascar, but the measurements he provides indicate that the animal was *S. robustus*. This species is known only from the north of Madagascar. The species is not considered threatened by IUCN (Hutson *et al*. 2001).

Characteristics	Measurements
Total length	135-168
Mass	41-50
Tail length	55-67
Foot	14-16
Ear	16-20
Tibia	23-28
Forearm	60-65
5th Metacarpal	54-58
Skull length	25.6
Condylobasal length	21.5

Echolocation: Calls of *S. robustus* consist of an FM sweep which terminates in a CF portion with maximum energy at around 35kHz. In cluttered situations, the call becomes more broadband and shorter in duration. The maximum energy may rise slightly to about 35kHz. In open situations, the calls become less broadband, longer in duration and, occasionally, the FM sweep may be almost non-existent. In such situation, the call will be almost CF with a slightly lower frequency of maximum energy.



Sonogram 17. Echolocation calls of *Scotophilus robustus* released from the hand.

Scotophilus borbonicus (Geoffroy Milne-Edwards, 1803)

Suborder: MICROCHIROPTERA	
Family: VESPERTILIONIDAE	**EN:**
Genus: *SCOTOPHILUS*	**FR:**

Peterson *et al.* (1995) doubted the existence of this species in Madagascar. It is distinguished from *S. robustus* by having a forearm less than 55mm. The species is listed as critically endangered by IUCN (Hutson *et al*. 2001). Hutcheon (1996) recorded capturing an individual in northeastern Madagascar, but the measurements given indicate the animal was *S. robustus*.

Miniopterus gleni (Peterson et al., 1995)

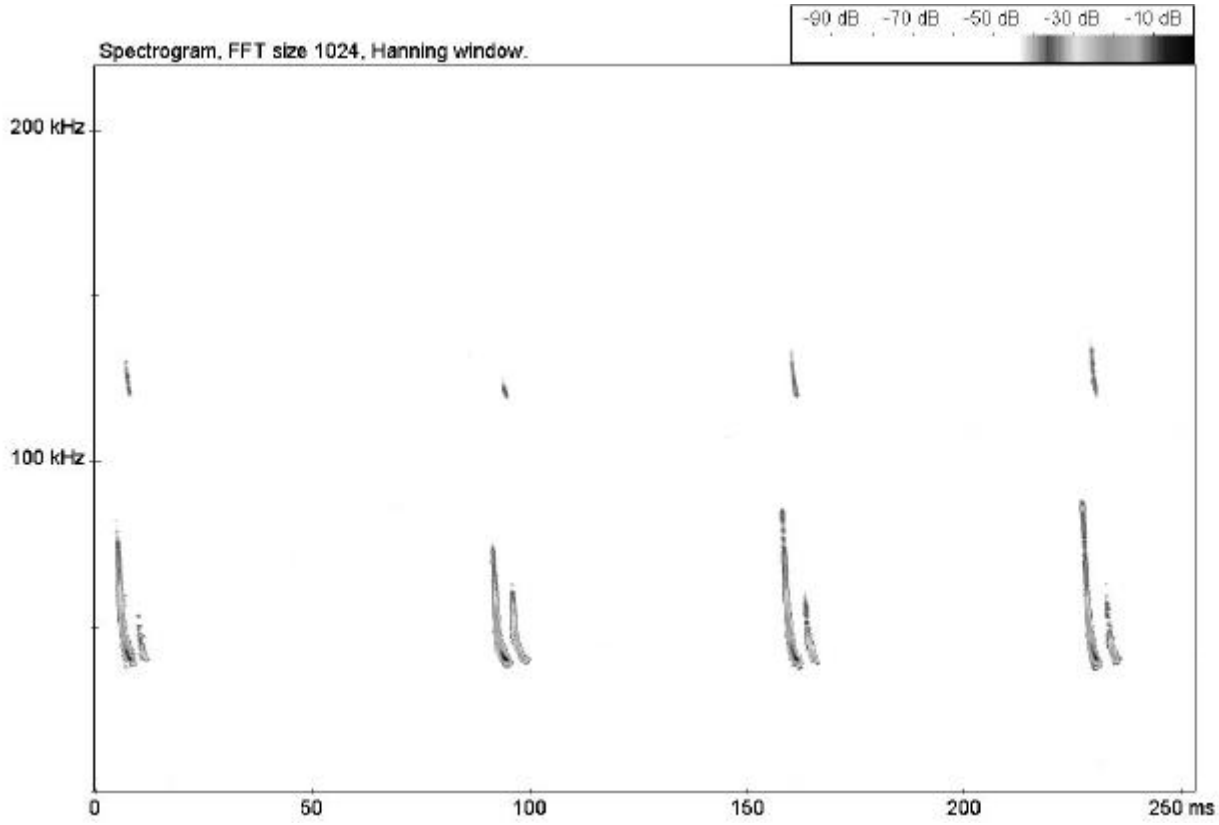
Suborder: MICROCHIROPTERA	
Family: VESPERTILIONIDAE	**EN:**
Genus: *MINIOPTERUS*	**FR:**

Figure 25. *Miniopterus gleni,* Ambodiadabo.

This is the largest species of *Miniopterus* in Madagascar and is endemic. The pelage is very long, dark and silky. Hair on the body is long (7 to 8mm) and clove brown and the ventral hair is about 5-6mm and a little bit paler than the back. The base of the ears is rounded and the tragus is uniform. The snout is hairy. The skull is large with a box-shaped cranium, with a rounded front. The second bone of the longest finger is about three times as long as the first bone. When the bat hangs by its hind feet, this lengthened terminal part of the third finger folds back upon the wing. The tail is completely enclosed within the interfemoral membrane and is proportionally longer than in other bats of the same size. There is no postcalcarial lobe. This species is widespread in Madagascar and not considered threatened by IUCN (Hutson *et al.* 2001).

Characteristics	**Measurements**
Tibia	18-21
Mass	12.5-14.5
Forearm	46-50
4th Metacarpal	40-45
5th Metacarpal	35-38
Skull length	16.7
Condylobasal length	16.25

Echolocation: Calls of *M. gleni* consist of an FM sweep which terminates in a CF portion with maximum energy at around 42kHz. The inter-pulse interval is about 73ms. In cluttered situations, the call becomes more broadband and shorter in duration. The maximum energy may rise slightly. In open situations, the calls become less broadband, longer in duration and, occasionally, the FM sweep may be almost non-existent. The inter-pulse interval is slightly longer than that of the pipistrelle species recorded.



Sonogram 18. Echolocation calls of *Miniopterus gleni*. Note the echo produced by the call 'bouncing off' a nearby solid object.

Miniopterus majori **(Thomas, 1906)**

Suborder: MICROCHIROPTERA	
Family: VESPERTILIONIDAE	**EN:**
Genus: *MINIOPTERUS*	**FR:**

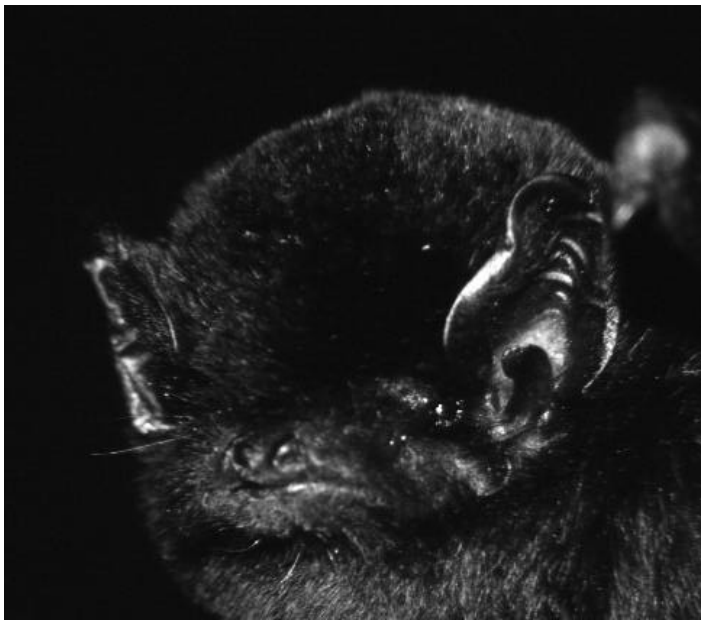
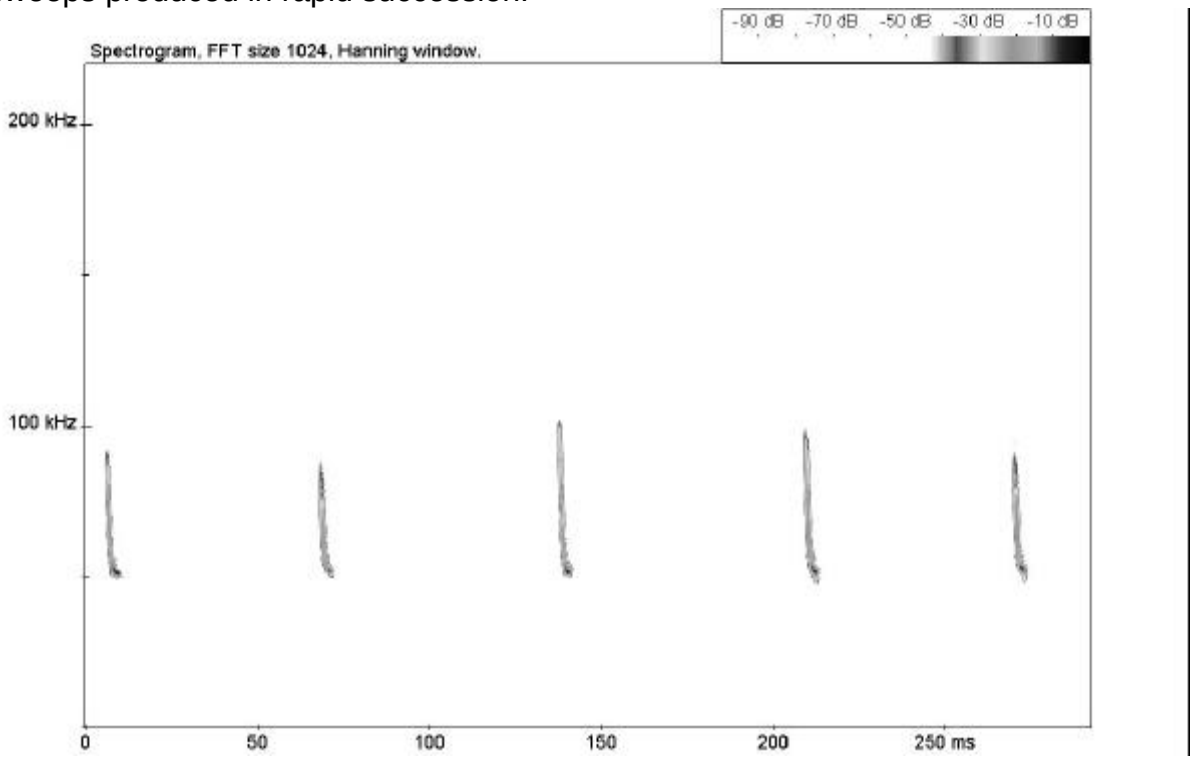


Figure 26. *Miniopterus majori*, Andasibe.

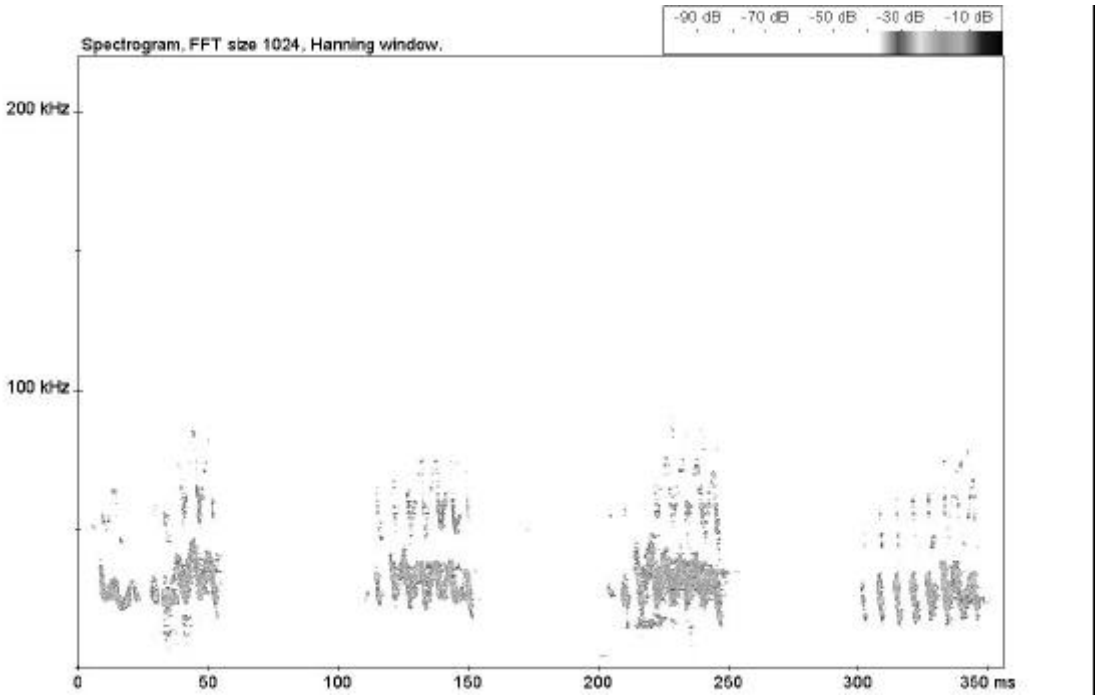
M. majori is endemic to Madagascar and resembles *M. schreibersi* of Africa but with a short forearm, slightly longer digits and a box-shaped narrow skull. It is easy to separate from the other Madagascar species by the significant length of the tibia, the forearm, the 3rd and 4th digits, and the longer and larger skull. The pelage is greyish-brown and generally slightly paler on the ventral side. The ears are moderately large and squarish in shape; the tragus is kidney-shaped and prominent. The second metacarpel of the longest digit is about three times as long as the first bone. When the bat hangs by its hind feet, this lengthened terminal part of the third finger folds back upon the wing. The tail is completely enclosed within the interfemoral membrane and is proportionally longer than in other bats of the same size. There is no postcalcarial lobe present. This species is widespread in Madagascar and listed as data deficient by IUCN (Hutson *et al*. 2001).

Characteristics	**Measurements**
Tibia	17-20
Mass	11.5
Forearm	41-47
4th Metacarpal	37-42
5th Metacarpal	34-37
Skull length	15.8
Condylobasal length	15.4

Echolocation: Calls of *M. majori* consist of an FM sweep which terminates in a CF portion with maximum energy at around 51kHz. The inter-pulse interval is about 75kHz. In cluttered situations, the call becomes more broadband and shorter in duration. The maximum energy may rise slightly. In open situations, the calls become less broadband, longer in duration and, occasionally, the FM sweep may be almost non-existent. Distress calls consist of a series of low frequency, high intensity FM sweeps produced in rapid succession.



Sonogram 19. Echolocation calls of *Miniopterus majori*.



Sonogram 20. Distress calls of *Miniopterus majori*.

Miniopterus fraterculus (Thomas & Schwann, 1906)

Suborder: MICROCHIROPTERA
Family: VESPERTILIONIDAE **EN: Lesser long-fingered bat**
Genus: *MINIOPTERUS* **FR:**

In Madagascar, *M. fraterculus* is separated from the other *Miniopterus* species by the fact that the 4th digit is much shorter, the skull is long with a prominent palate. The pelage is greyish to greyish-brown. The second metacarpal of the longest finger is about three times as long as the first bone. When the bat hangs by its hind feet, this lengthened terminal part of the third finger folds back upon the wing. The tail is completely enclosed within the interfemoral membrane and is proportionally longer than in other bats of the same size. There is no postcalcarial lobe present. Although represented in various museum collections, the species has not been recognised with any degree of certainty for some time in Madagascar except for a specimen collected by Goodman (1998) in Reserve Speciale d'Anjanaharibe-Sud. It is not considered threatened by IUCN (Hutson *et al.* 2001).

Characteristics	Measurements
Tibia	17-19
Forearm	40-45
4DME	37-40
5th Metacarpal	34-38
Mass	8-12
Skull length	14.7
Condylobasal length	14

Echolocation: Not recorded

Miniopterus manavi **(Thomas, 1906)**

Suborder: MICROCHIROPTERA	
Family: VESPERTILIONIDAE	**EN:**
Genus: *MINIOPTERUS*	**FR:**

Figure 27. Miniopterus manavi, Ambodiadabo and Amabanizana.

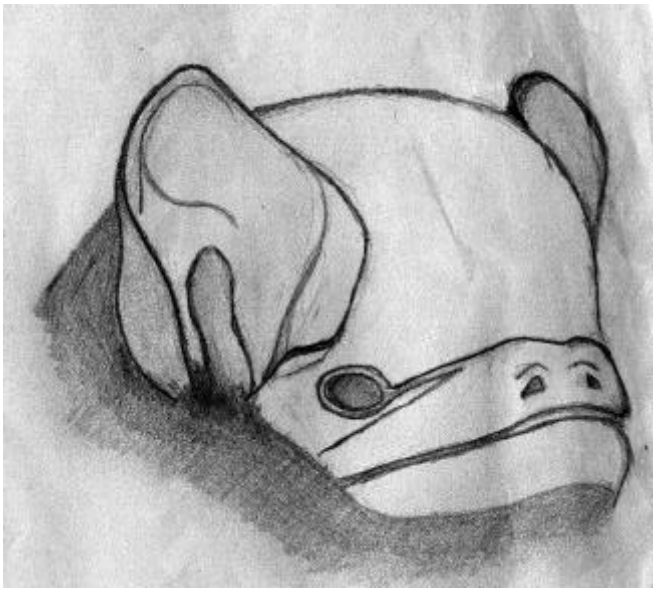
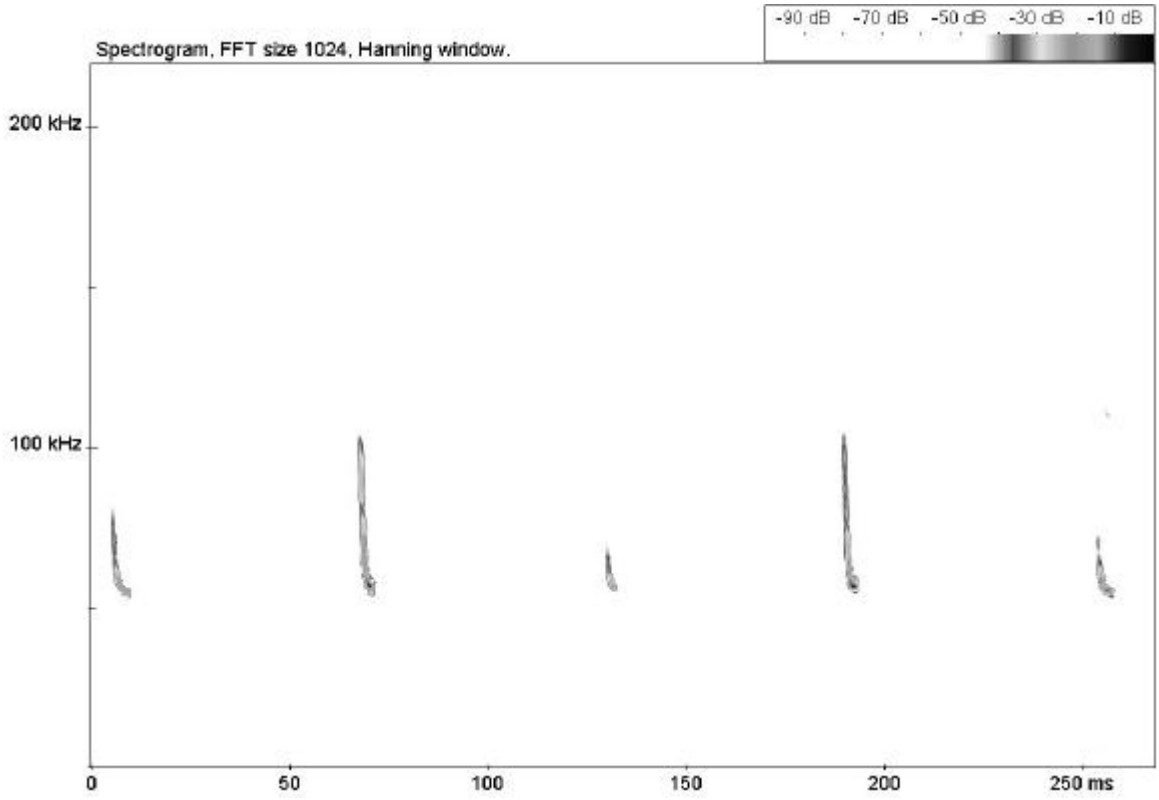


Figure 28. Miniopterus manavi, St Augustin

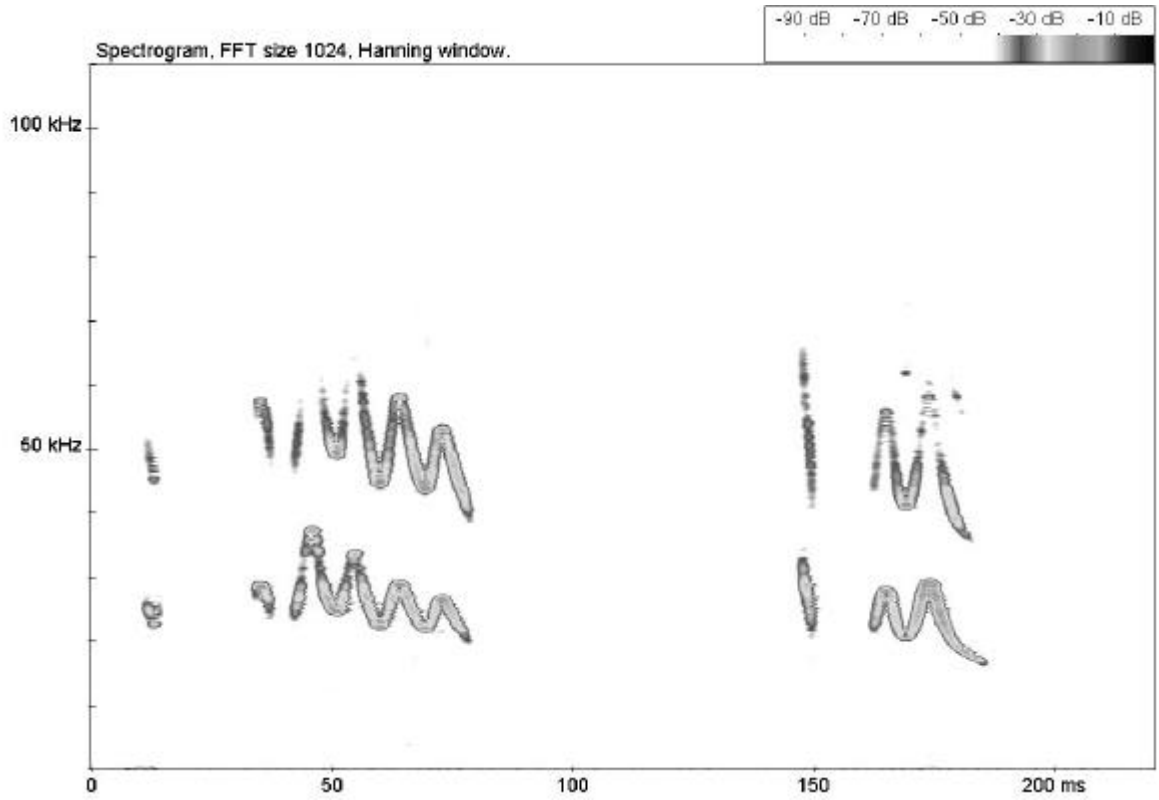
M. manavi is restricted to Madagascar and Grand Comoro. This is the smallest species of *Miniopterus* in Madagascar. It is distinguished from *M. fraterculus*, the species to which it is most related, by the shorter forearm, metacarpals and tibia. The pelage is variously greyish-brown to reddish-brown. The ears are angular and the tragus prominent. The second bone of the longest finger is about three times as long as the first bone. When the bat hangs by its hind feet, this lengthened terminal part of the third finger folds back upon the wing. The tail is completely enclosed within the interfemoral membrane and is proportionally longer than in other bats of the same size. There is no postcalcarial lobe present. In some members of the population at Ambanizana the tragus is reduced or absent. This species is widespread in Madagascar and listed as data deficient by IUCN (Hutson *et al.* 2001).

Characteristics	**Measurements**
Tibia	13.7-15.2
Forearm	32-39
4th Metacarpal	31.1-34.1
5th Metacarpal	29-31.9
Mass	5.5-7.25

Echolocation: Calls of *M. manavi* consist of an FM sweep which terminates in a CF portion with maximum energy at around 57kHz. In open situations, the call becomes more broadband and shorter in duration. The maximum energy may rise slightly. In open situations, the calls become less broadband, longer in duration and, occasionally, the FM sweep may be almost non-existent. Distress calls are of high intensity and consist of a series of FM ‘trills’.



Sonogram 21. Echolocation calls of *Miniopterus manavi*.



Sonogram 22. Distress calls of *Miniopterus manavi*.

Myzopoda aurita (Milne-Edwards & Grandidier, 1878)

Suborder: MICROCHIROPTERA
Family: MYZOPODIDAE **EN: Old World sucker-footed bat**
Genus: *MYZOPODA* **FR: Chauve-Souris malgache à pieds à ventouses**

Figure 29. *Myzopoda aurita*, Ambodiadabo

M. aurita is endemic to Madagascar. This bat may be recognised by the adhesive pads or discs on the wrists and ankles (they do not have a stalk). Has large pointed ears with a tragus and a unique mushroom-shaped process. The lips are wide, and the upper lip extends beyond the lower. The thumb has a vestigial claw, and the tail extends beyond the tail membrane. The pelage is moderately dense and mid-brown, with some weak russet tinges. The upper lip extends significantly beyond the lower. The species appears widespread but rare in eastern Madagascar and a few examples

are known from the west of the island. The species is considered vulnerable by IUCN (Hutson *et al.* 2001).

Only three sucker-footed bats exist in the world; two in South America and the unrelated *Myzopoda* in Madagascar (Schliemann 1970, 1971). It is considered one of the rarest bats in Madagascar. We have caught three specimens of this bat and are aware of just a few other individuals known to science. Schliemann and Maas (1978) considered the species to be restricted to the forests of the eastern coast. A specimen found by Hoogstraal in 1947 was roosting in a rolled-up leaf of *Ravenella*, suggesting the species has similar habits to other sucker-footed bats. We have heard the animal on Nosy Mangabe, in the garden of a hotel in Maroantsetra and on the central plateau at Andasibe Its call is distinctive even on a heterodyne detector and so the animals should prove easy to find in future. However it appears to be a rare member of all communities which make it potentially vulnerable to extirpation.

Characteristics	**Measurements**
Weight	8-10.5
Total Length	95-115
Foot	7
Ear length	27-35
Forearm	47-50

Echolocation: The echolocation calls of *Myzopoda aurita* are very distinct and consist of a very shallow, almost CF sweep, often broken up into a series of components, followed by an FM sweep. The frequency of maximum energy is at about 42kHz and is diagnostic. Individuals in flight cages produce calls of shorter duration and shorter inter-pulse intervals than those recorded in the field. As the inter-pulse interval increases, so do the number of components that made up each shallow FM call. The first harmonic is dominant, but the fundamental can occasionally be seen at around 21kHz (maximum energy). The echolocation calls are of medium intensity. The distress call consists of a series of ‘trills’.

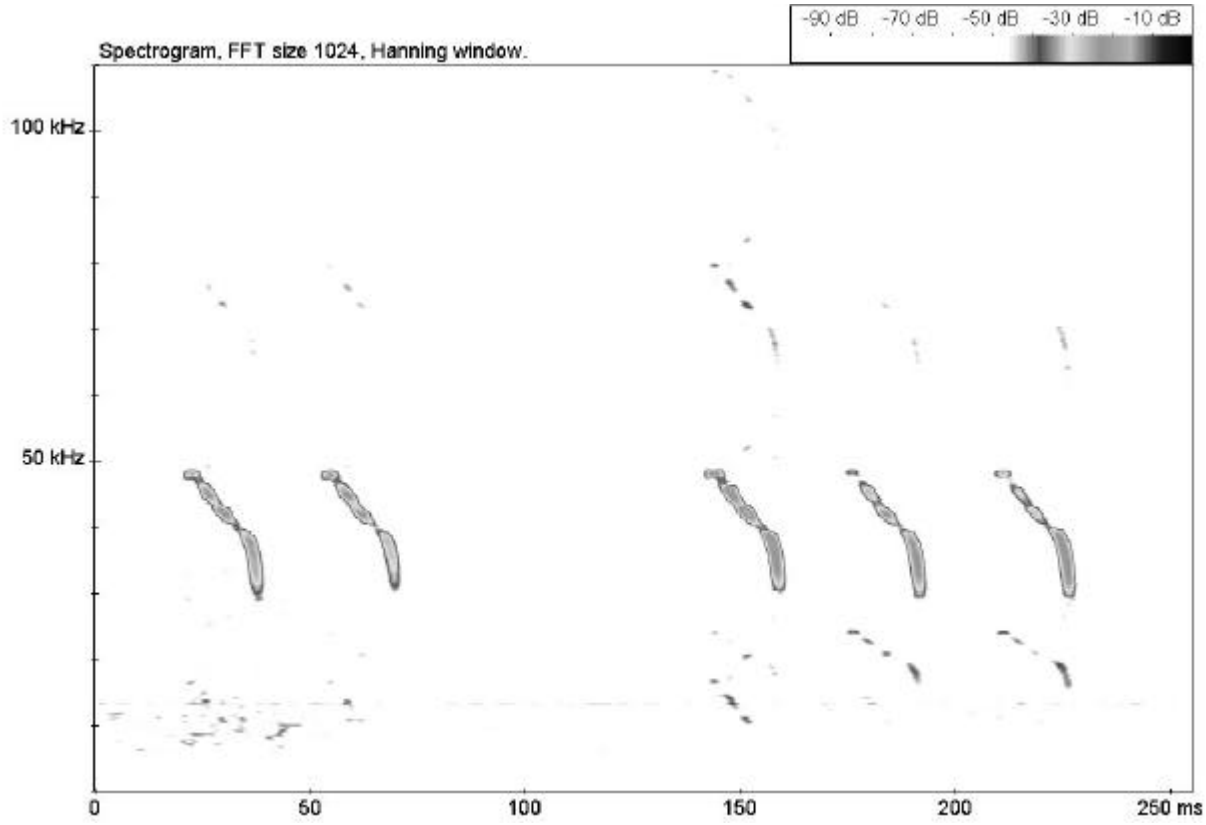
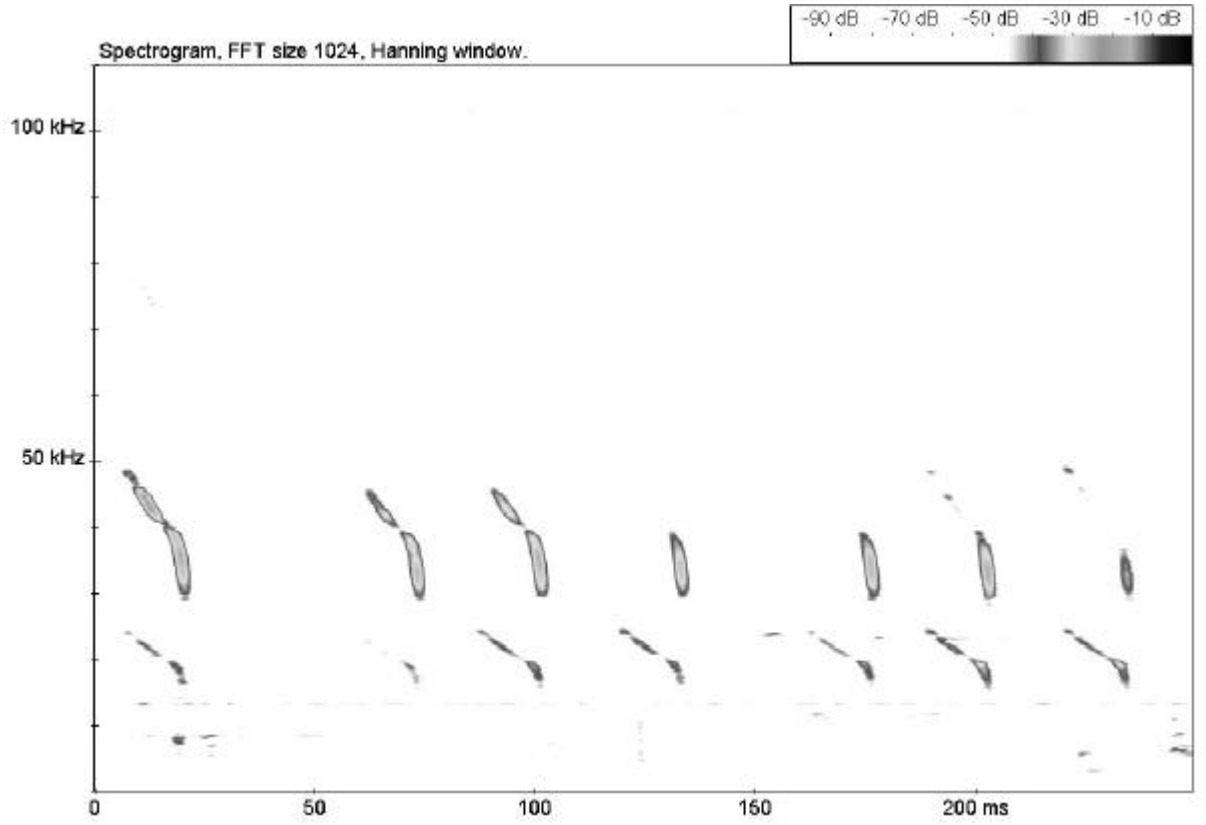
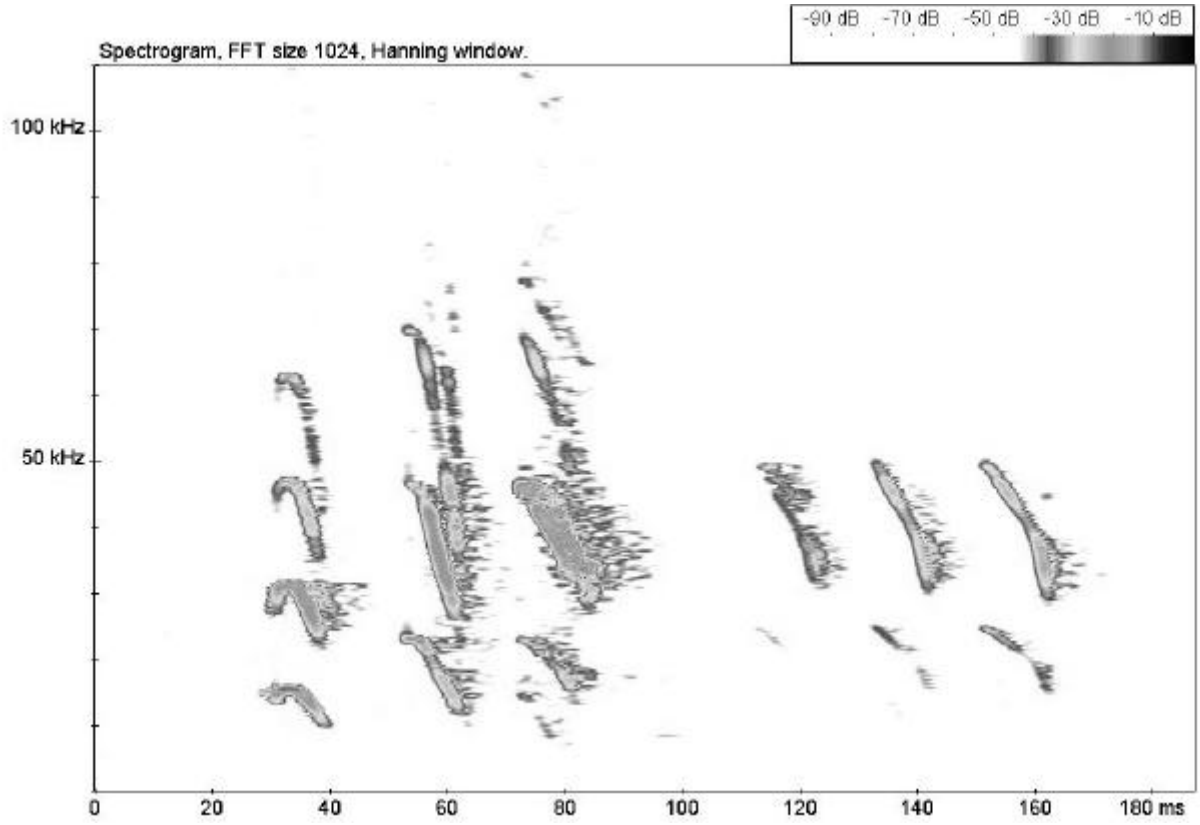


Figure x. Echolocation calls of *Myzopoda aurita*



Sonogram 23. Echolocation calls of *Myzopoda aurita*



Sonogram 24. Distress calls of *Myzopoda aurita*

Mormopterus jugularis (Peters, 1865)

Suborder: MICROCHIROPTERA	
Family: MOLOSSIDAE	**EN: Peter's Goblin bat**
Genus: *MORMOPTERUS*	**FR:**

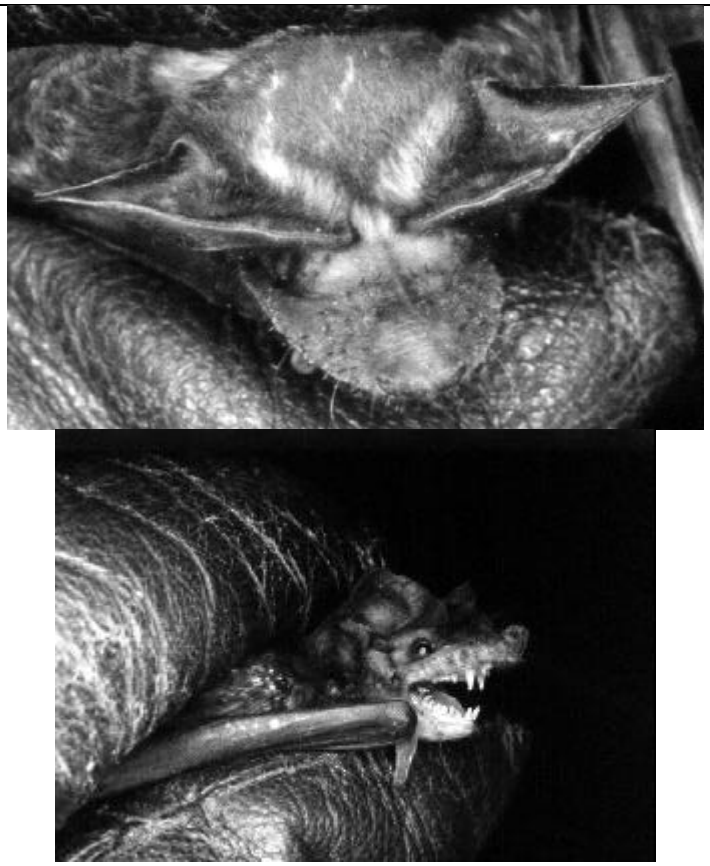
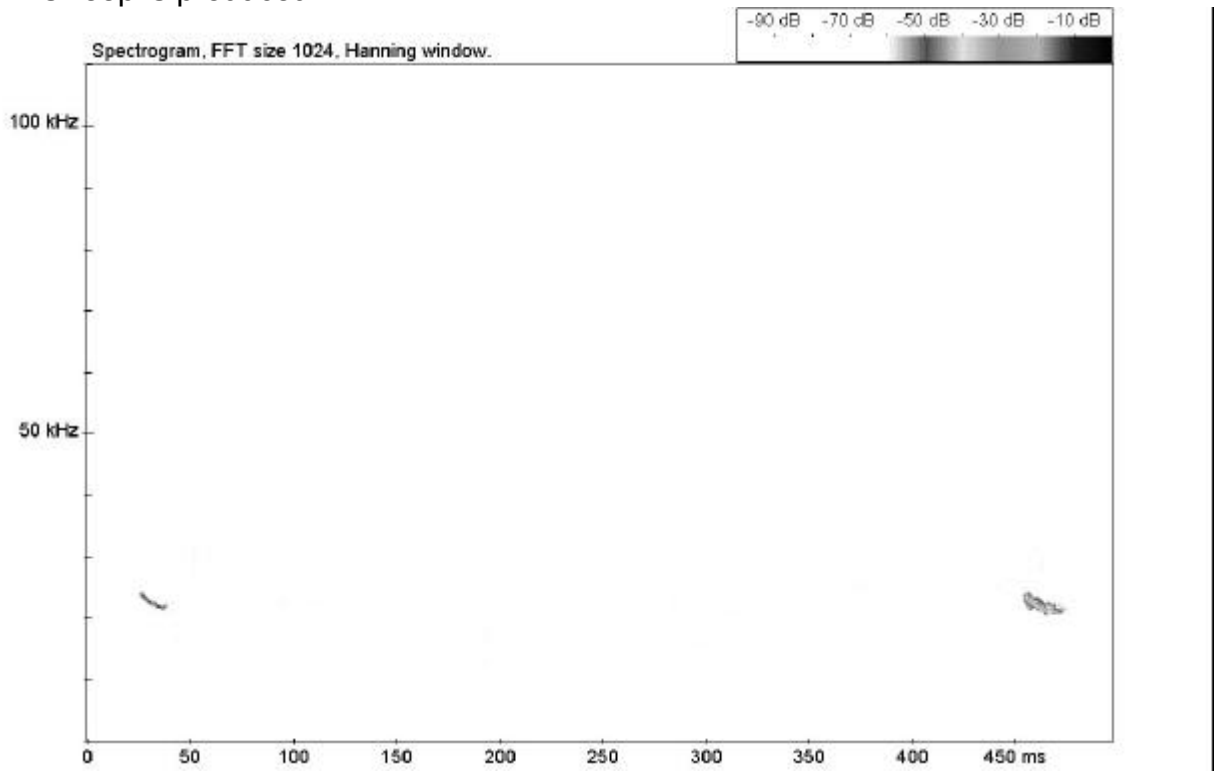


Figure 30*. Mormopterus jugularis* St Augustin

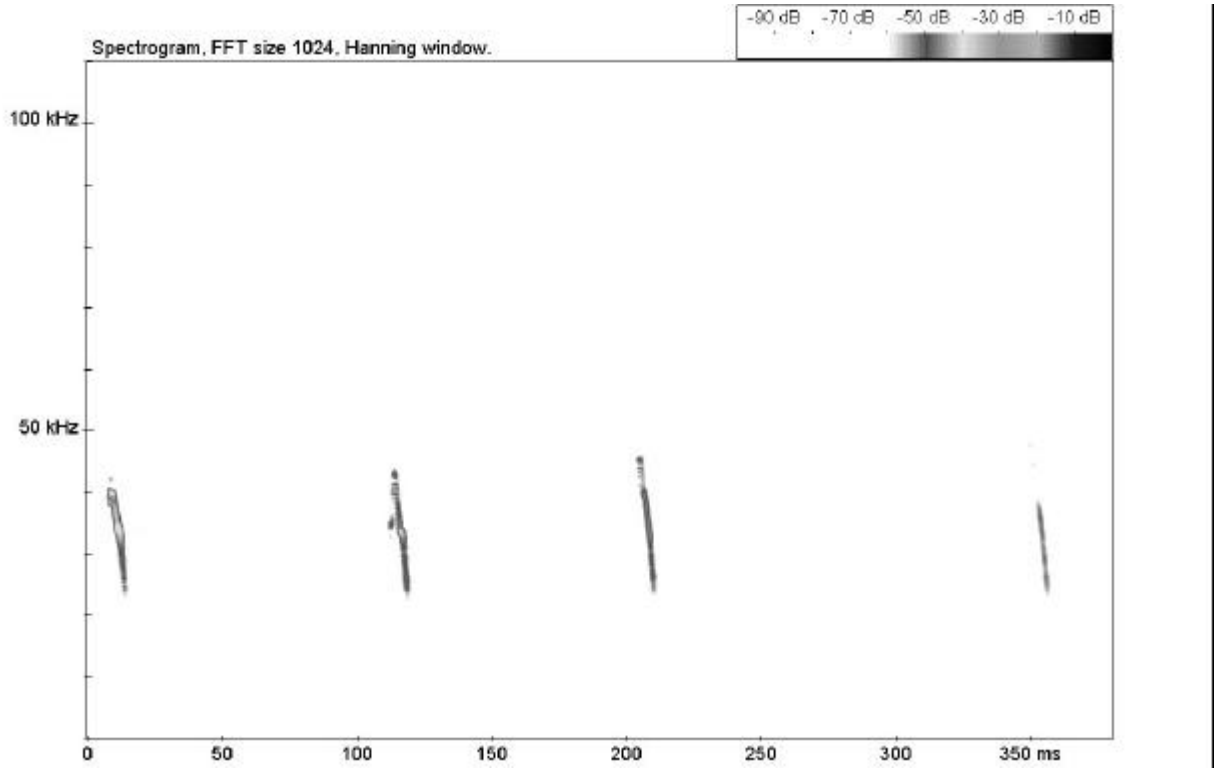
M. jugularis is endemic to Madagascar. The pelage is soft and dense with greyish-brown to charcoal upperparts and paler underparts. The snout is blunt and slightly upturned, and the ears are large, prominent and broad at their base. Males have well developed throat glands in the adults. Some authors have speculated on the presence of the Comorian *M. acetabluosus* in Madagascar, but no specimens have been recorded. *M. acetabulosus* is similar in size to *M. jugularis* but distinct on the basis of ear shape. In *M. acetabulosus* they are triangular, while in *M. jugularis* they are rounded. We have included both in the key. *M. jugularis* is widespread in central and southern Madagascar. Both species are considered vulnerable by IUCN (Hutson *et al.* 2001).

Characteristics	**Measurements**
Forearm	36-39
Mass	8.5-11.5
3rd Metacarpal	36-39
4th Metacarpal	34-37
5th Metacarpal	23-27
Length of Skull	16-18
Condylobasal length	15-17

Echolocation: The echolocation calls of *M. jugularis* are very variable. In open situations a shallow FM sweep is produced with maximum energy at about 24kHz, with an inter-pulse interval of about 192ms. In closed environment a relatively steep FM sweep is produced.



Sonogram 25. Echolocation calls of *Mormopterus jugularis* in an open environment



Sonogram 26. Echolocation calls of *Mormopterus jugularis* in a cluttered environment

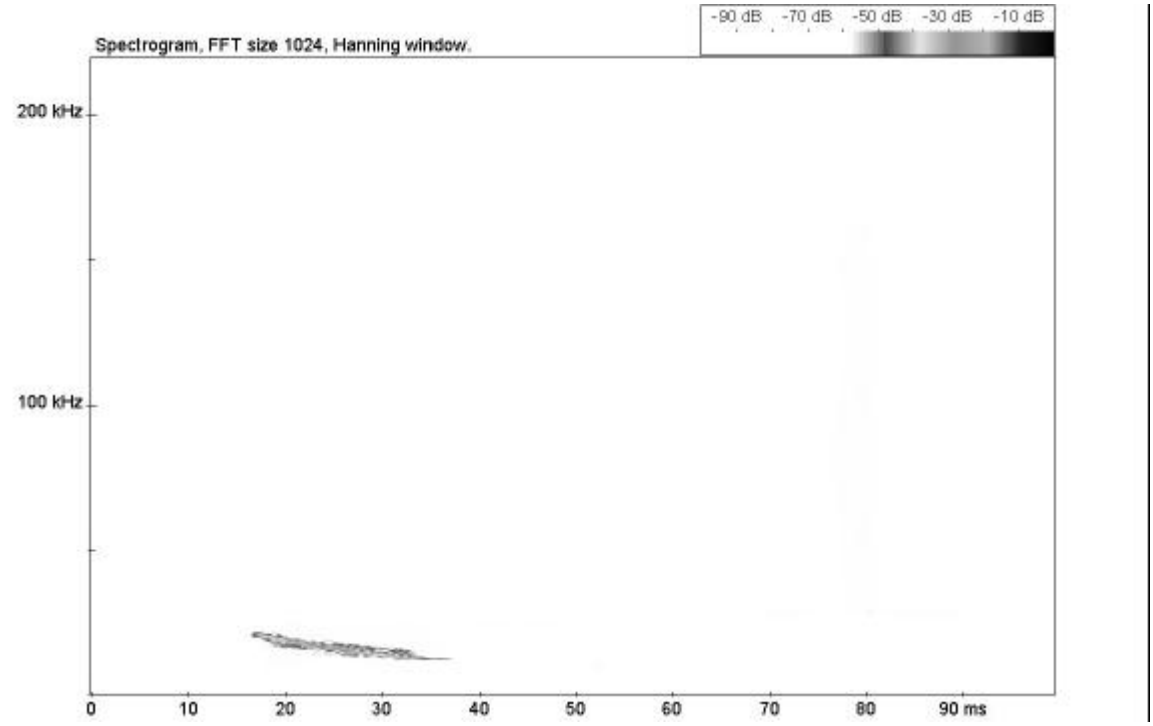
Tadarida fulminans fulminans (Thomas, 1903)

Suborder: MICROCHIROPTERA	
Family: MOLOSSIDAE	**EN: Large free-tailed bat**
Genus: *TADARIDA*	**FR:**

The body is of average size, the ears don't meet, but are very close at the base; lip is smooth. The body is dark chestnut-brown dorsally and pale grey to whitish on the chest and belly. The wings are noticeably paler than the body. The tragus and antitragus are well developed. The head is small and relatively narrow. The species is known only from a single specimen collected at Fianarantsoa (Thomas 1903) and not considered threatened by IUCN (Hutson *et al.* 2001).

Characteristics	Measurements
Forearm	57-59
3rd Metacarpal	60
4th Metacarpal	56
5th Metacarpal	32
Length of skull	23
Condylobasal length	22

Echolocation: Although not recorded in Madagascar, in South Africa the dominant (17kHz) and minimum (14kHz) of its echolocation call is low and just audible to human hearing (P. Taylor, pers. comm.). These calls are about 20ms in length, narrow in bandwidth (14-27khz) and shallow FM.



Sonogram 27. Call of *Tadarida fulminans* based on diagrammatic representation from Taylor (2000).

Tadarida (Chaerephon) leucogaster (Grandidier, 1869)

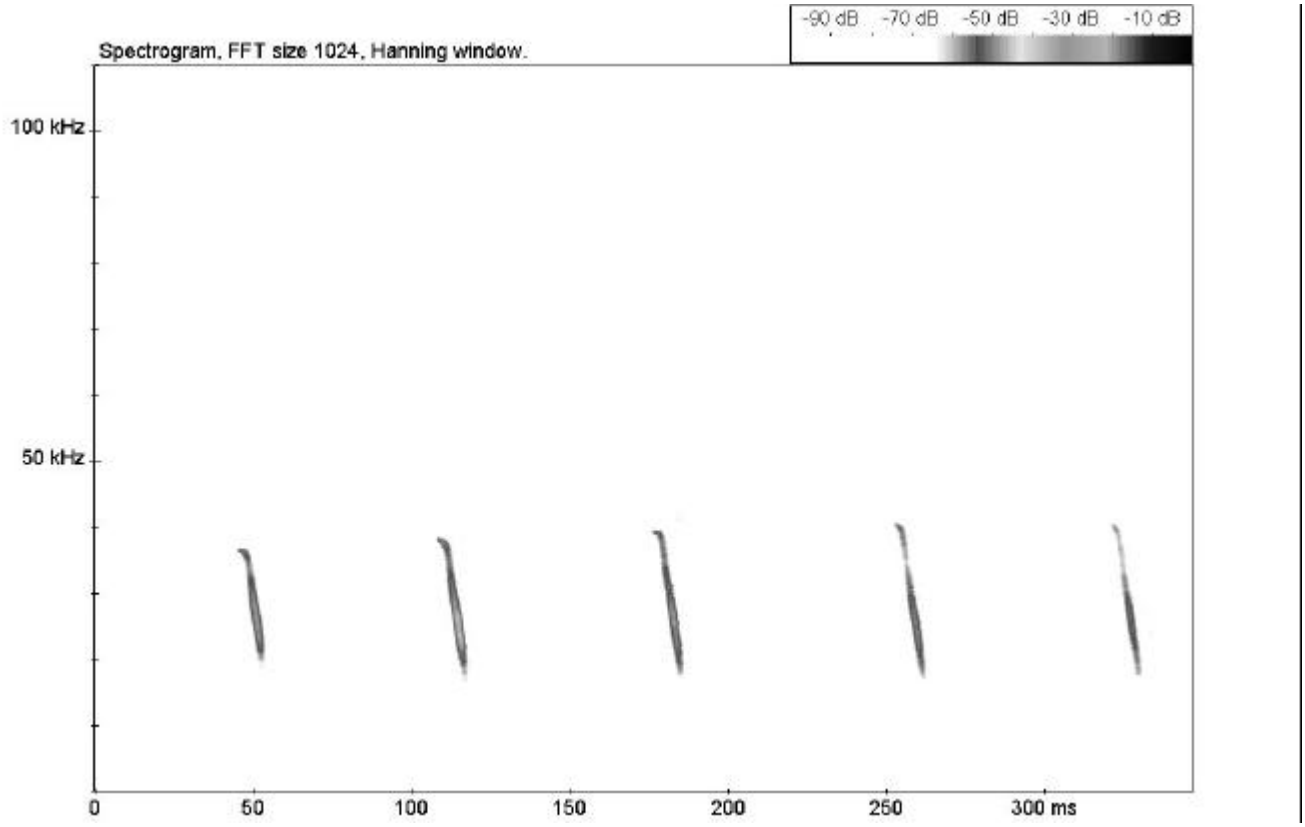
Suborder: MICROCHIROPTERA
Family: MOLOSSIDAE **EN:**
Genus: *TADARIDA* **FR:**
Subgenus: *CHAEREPHON*

Figure 31. *Tadarida leucogaster*, Andasibe.

Small Malagasy species. Lip is wrinkled. Tragus is small and square. Antitragus is large and square. The upper part of the throat and chest are dark brown, the abdomen is white and the wing membranes are whitish/ grey. Sometimes considered to be a subspecies of *T. pumila*. This bat has been found in the extreme north and south of Madagascar, but its overall distribution remains uncertain. It is listed as data deficient by IUCN (Hutson *et al.* 2001).

Characteristics	Measurements
Forearm	32-38
Mass	8.5-9
3rd Metacarpal	34-41
4th Metacarpal	33-38
Length of Skull	15-17
Condylobasal length	14-16

Echolocation: In cluttered environments a steep FM call is produced. There is no information available on calls in its natural open environment.



Sonogram 28. Echolocation calls of *Tadarida (Chaerephon) leucogaster* in a cluttered environment

Tadarida (Chaerephon) pumila (Cretzschmar, 1826)

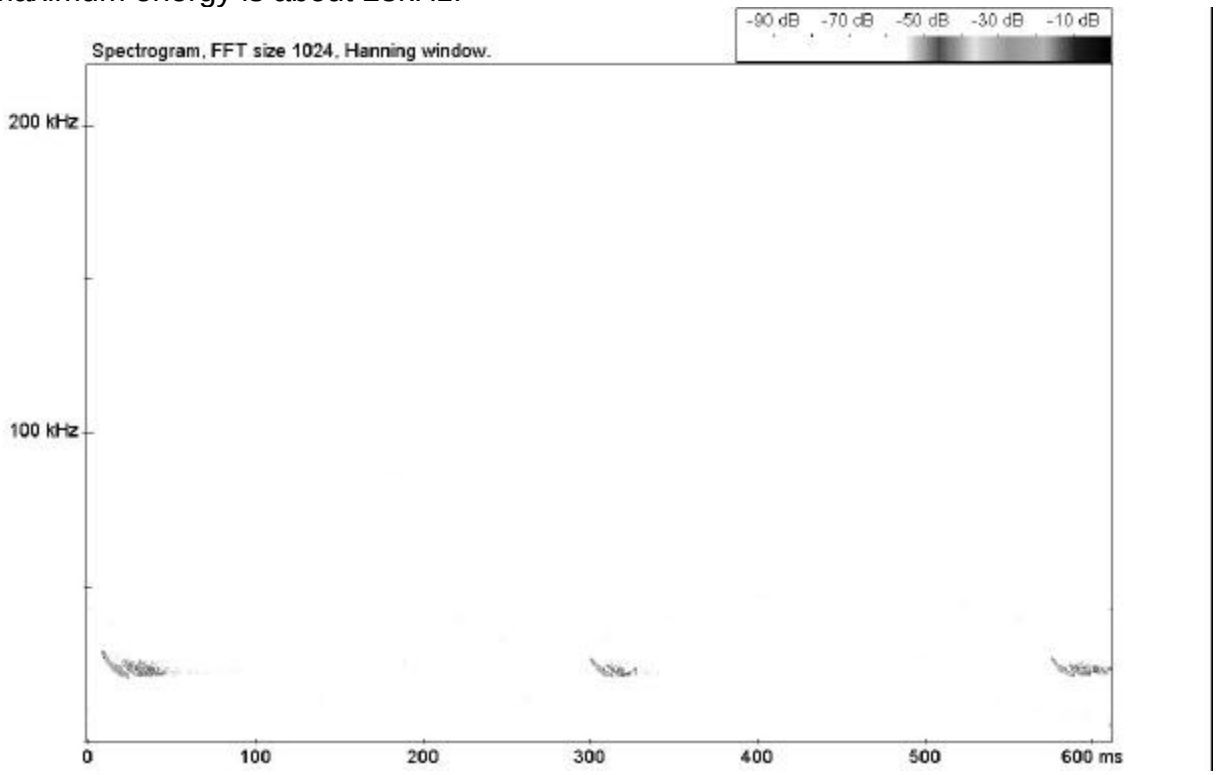
Suborder: MICROCHIROPTERA	
Family: MOLOSSIDAE	**EN: Little free-tailed bat**
Genus: *TADARIDA*	**FR:**
Subgenus: *CHAEREPHON*	

Figure 32. *Tadarida pumila*, Andasibe

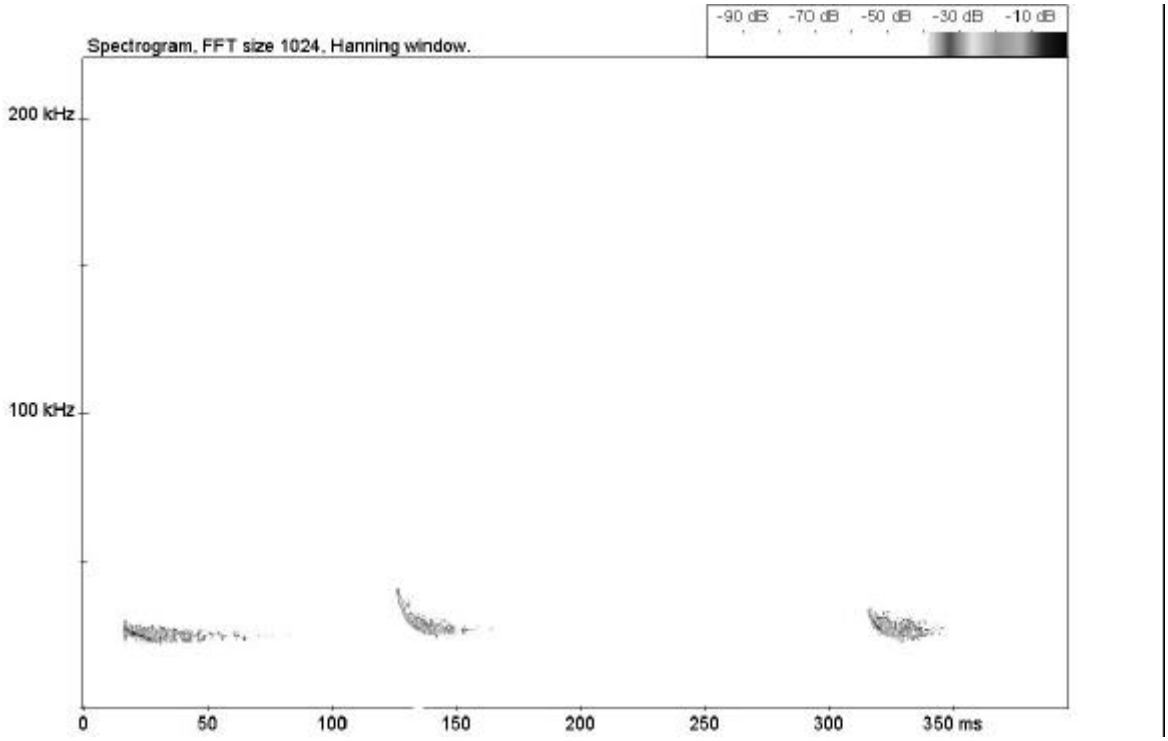
This species is large compared to *T. (Chaerephon) leucogaster*. Tragus is small, sharp and straight. Antitragus is large and square. The tip of the fur is woollen, not very long, but thick. The colour of the dorsal surface is blackish/ brown, as are the ears, although the colour is variable. Slightly paler underneath. Known only from eastern Madagascar. The species is not listed by IUCN (Hutson *et al.* 2001).

Characteristics	Measurements
Forearm	38-41
3rd Metacarpal	38-43
Mass	9-11.5
4th Metacarpal	37-41
5th Metacarpal	24-27
Length of Skull	17-18
Condylobasal length	15-16

Echolocation: *T. pumila* produces low frequency echolocation calls of long duration (about 13ms) and with a high inter-pulse interval of about 173ms. The frequency of maximum energy is about 28kHz.



Sonogram 29. Echolocation calls of *Tadarida pumila* in an open environment



Sonogram 30.. Echolocation calls of *Tadarida pumila* in an open environment

Tadarida (Mops) leucostigma **(Allen, 1918)**

Suborder: MICROCHIROPTERA	
Family: MOLOSSIDAE	**EN:**
Genus: *TADARIDA*	**FR:**
Subgenus: *MOPS*	

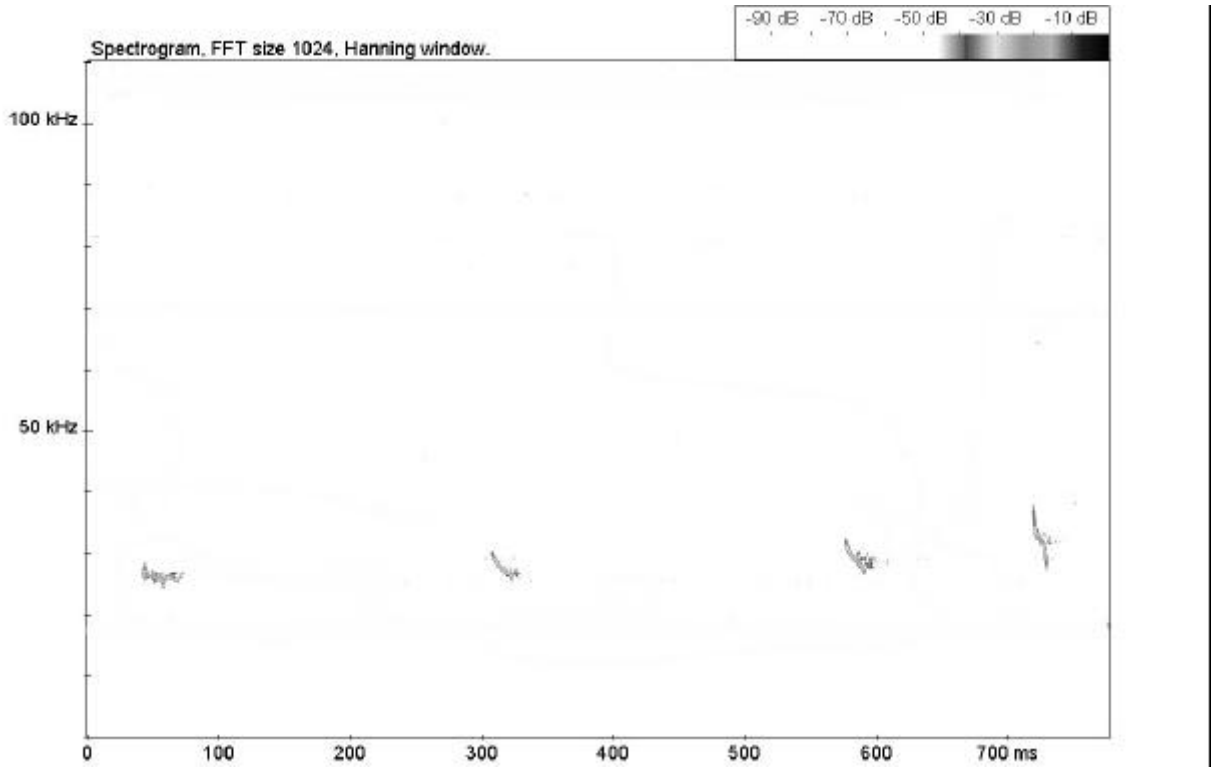
Figure 33. *Tadarida leucostigma*, Maroantsetra and Ambanizana

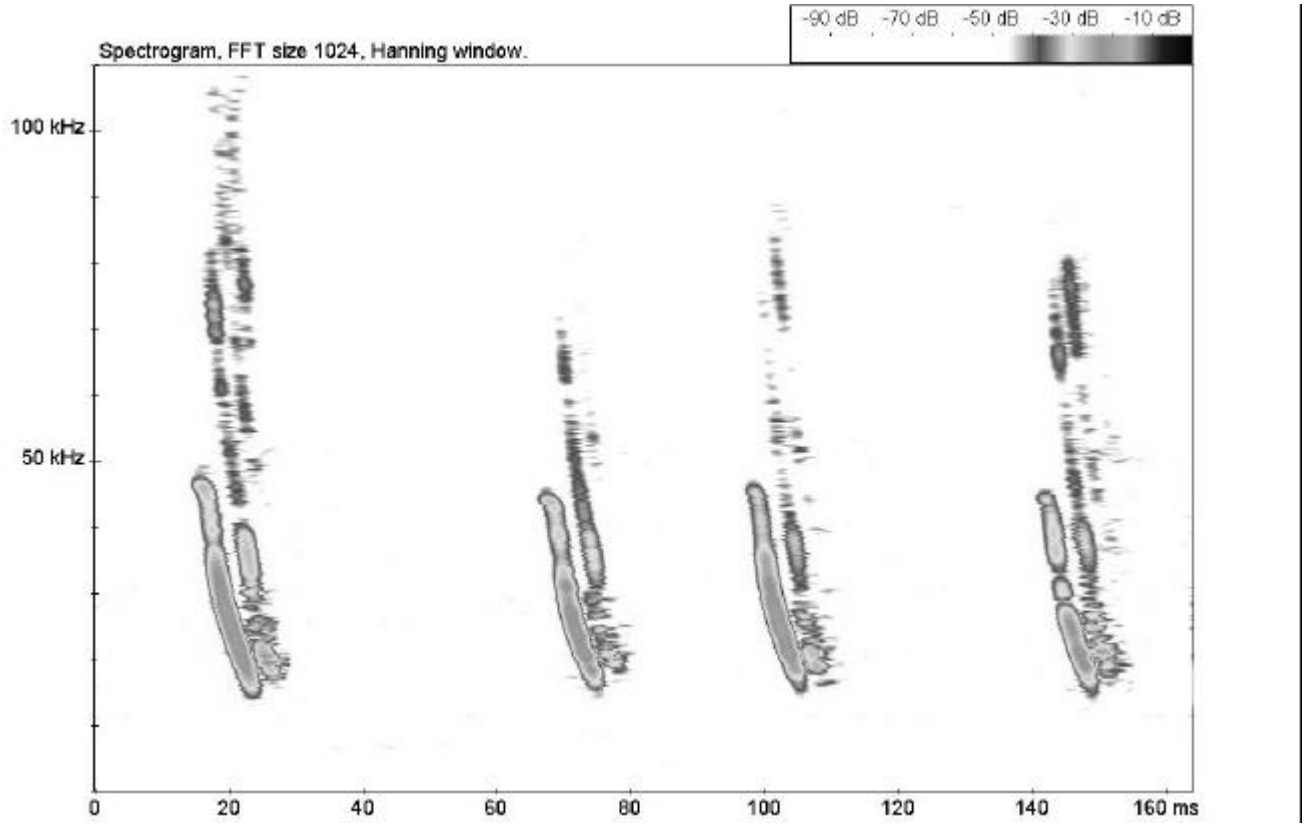
This species is endemic to Madagascar. The body is of average size, and heavy. Pelage is short and the colour is variable, in general greyish brown or brownish, sometime reddish on the top and more or less white on the top. Ears join at a short tuft of hair. The tragus is small and the antitragus is relatively large. The species is widespread in Madagascar and listed as data deficient by IUCN.

We have found this bat in prisons, hospitals, libraries and churches, frequently in groups of hundreds or more. They are sometimes unpopular because of their large group sizes and unusually strong smell.

Characteristics	Measurements
Forearm	42-45
3rd Metacarpal	43-46
Mass	12.5-22.5
4th Metacarpal	42-46
5th Metacarpal	27-30
Length of Skull	20-24
Condylobasal length	17-20

Echolocation: Echolocation: The echolocation calls of this species in a cluttered environment are very broadband FM sweeps produced in rapid succession. In an open environment the calls are of constant frequency with maximum energy at about 26kHz). Generally they use a combination of both the CF and variations on FM shaped calls.





Sonogram 31. Echolocation calls of *Tadarida (Mops) leucostigma* in an open environment

Tadarida (Mops) midas miarensis **(Grandidier, 1869)**

Suborder: MICROCHIROPTERA
Family: MOLOSSIDAE **EN: Midas free-tailed bat**
Genus: *TADARIDA* **FR:**
Subgenus: *MOPS*

This species is endemic to Madagascar. It is a large bat with large and rounded ears, with a small join where the ears meet medially, but without a distinctive crest of hair. Tragus is small and antitragus is large. The coat is relatively short and the colour is variable, although often dark brown above and paler tawny with white tipped hairs below. Only known from southern Madagascar, the species is not listed by IUCN (Hutson *et al.* 2001). Rasolozaka (1994) records the species from the Foret de Zombitse.

Characteristics	**Measurements**
Forearm	61-64
3rd Metacarpal	62-65
4th Metacarpal	60-63
5th Metacarpal	36-38
Length of Skull	27-29
Condylobasal length	24-27

Echolocation: Unknown

Otomops madagascariensis (Dorst, 1953)

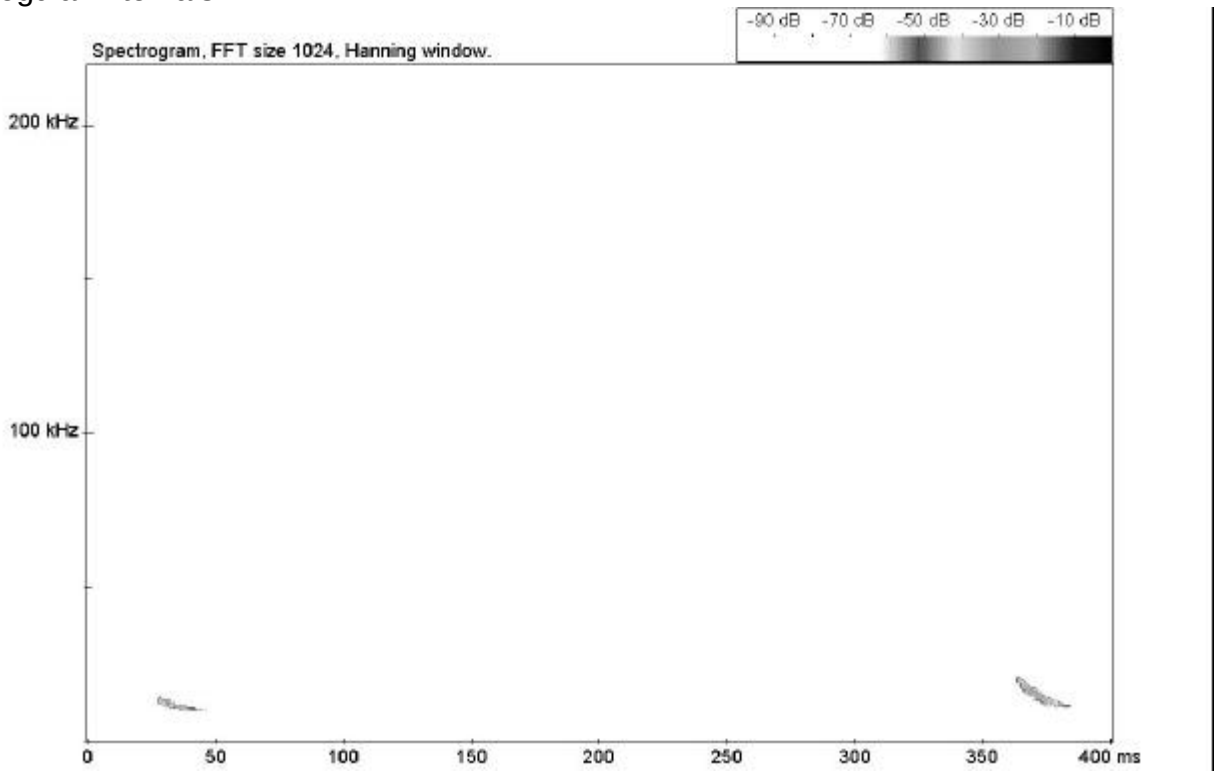
Suborder: MICROCHIROPTERA	
Family: MOLOSSIDAE	**EN: Madagascar free-tailed bat**
Genus: *OTOMOPS*	**FR:**

Figure 35. *Otomops madagascariensis*, St Augustin.

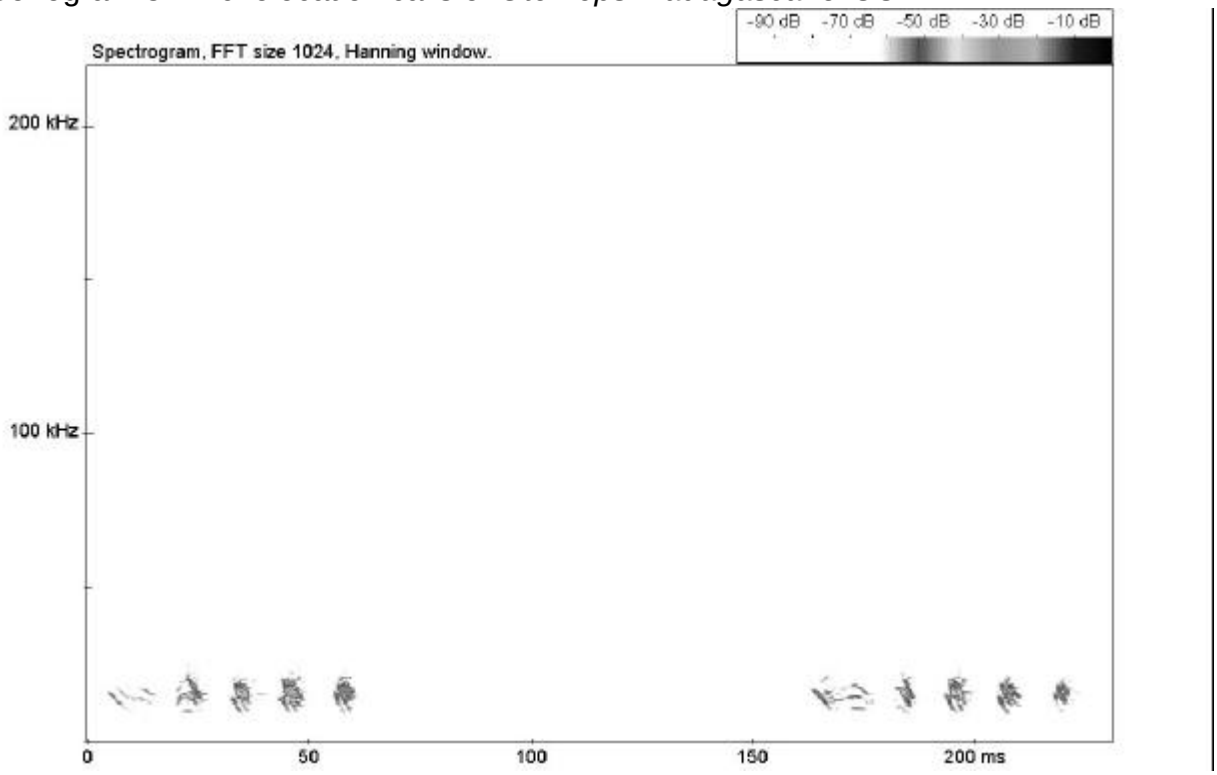
This endemic species is of average size. It was previously known as *O. martiensseni* , and some doubt remains over its classification. The coat is dark and the skull is narrow, long and light. Males are significantly larger than females. The colour of the coat is identical for males and females. It has a peculiarly flattened head and large ears. The upperparts vary from dark brown to reddish brown, with the underparts generally a slightly paler brown. There may also be a greyish area on the nape and upper dorsal region. The ears are 30-35mm in length and directed forward at a very oblique angle. Only known from the west of Madagascar, the species is listed as vulnerable by IUCN (Hutson *et al.* 2001). Hutcheon (1997) found a large roost of the species in a cave at Ankarana Reserve. We have only found the species in caves.

Characteristics	**Measurements**
Forearm	60-65
Mass	18.5-29.5
3rd Metacarpal	61-66
4th Metacarpal	54-60
5th Metacarpal	29-32
Length of Skull	23-27
Condylobasal length	21-26

Echolocation: Produces a very long shallow FM call, which is almost CF in structure with maximum energy at about 15kHz. The inter-pulse interval is very high (about 320ms). Distress calls consist of a series of low frequency FM sweeps repeated at regular intervals.



Sonogram 32. Echolocation calls of *Otomops madagascariensis*



Sonogram 33. Distress calls of *Otomops madagascariensis*

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Key to the bats of Madagascar

1.
Has a claw on the thumb, and on the second digit. Teeth of the frugivorous type (2)

Has claw on the thumb, but not on the second digit. Teeth of the insectivorous type (4)

Figure 36. A fruit bat (*Rousettus*). The claw on the second digit is visible below the nose.

2.
No tail present. *Pteropus r. rufus*

Tail present (3)

3.
Forearm much greater than 95 mm. *Eidolon dupreanum*

Forearm much less than 95 mm. *Rousettus m. madagascariensis*

4.
Has fixed suckers on wrists and ankles. *Myzopoda aurita*

No suckers (5)

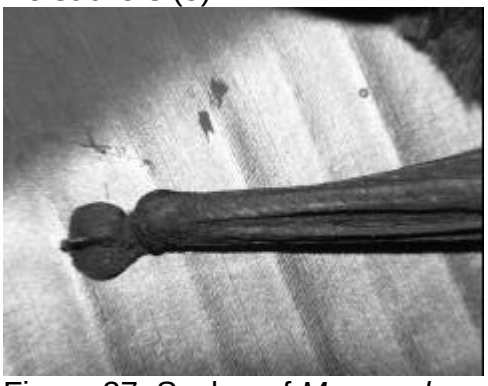


Figure 37. Sucker of *Myzopoda*

5.
Nose leaf present (can be slit nosed) (6)

No nose leaf present (10)

6.
Muzzle divided by a longitudinal furrow with fleshy dermal outgrowths. Tail terminates in a T-shaped tip (A). *Nycteris madagascariensis*

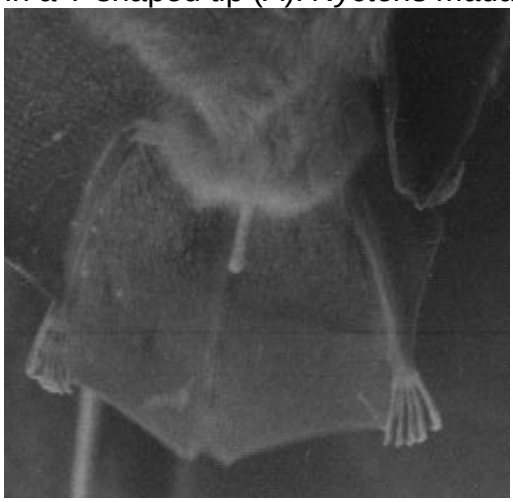


Figure 38. Tail of *Nycteris*

Face with well-developed nose-leaf covering muzzle (7)

7.
Forearm greater than 75 mm. Top of nose-leaf not very complex and is rounded [39A]. *Hipposideros c. commersoni*

Forearm less than 75 mm. Nose leaf is trident-shaped [39B] (8)

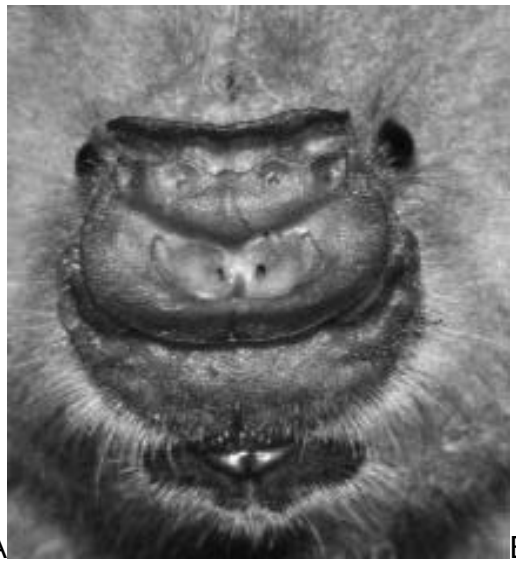
A  B 

Figure 39. Noseleaves of *Hipposideros* (A) and *Triaenops* (B)

8.
Forearm greater than 48 mm. Ears (from the notch) smaller than 15 mm. *Triaenops rufus*

Forearm less than 48 mm. Ears (from the notch) greater than 15 mm (9)

9. (Note: May be the same species)

3rd metacarpal greater than 35 mm. Tail less than 20 mm. Dorsal pelage is grey-black. *Triaenops auritus*

3rd metacarpal less than 35 mm. Tail greater than 20 mm. Dorsal pelage is grey-brown. *Triaenops furculus*

10.
Free tail. Does not include slight extension past interfemoral membrane (<5mm) [40A] (21)

Tail enclosed with interfemoral membrane [40B] (11)

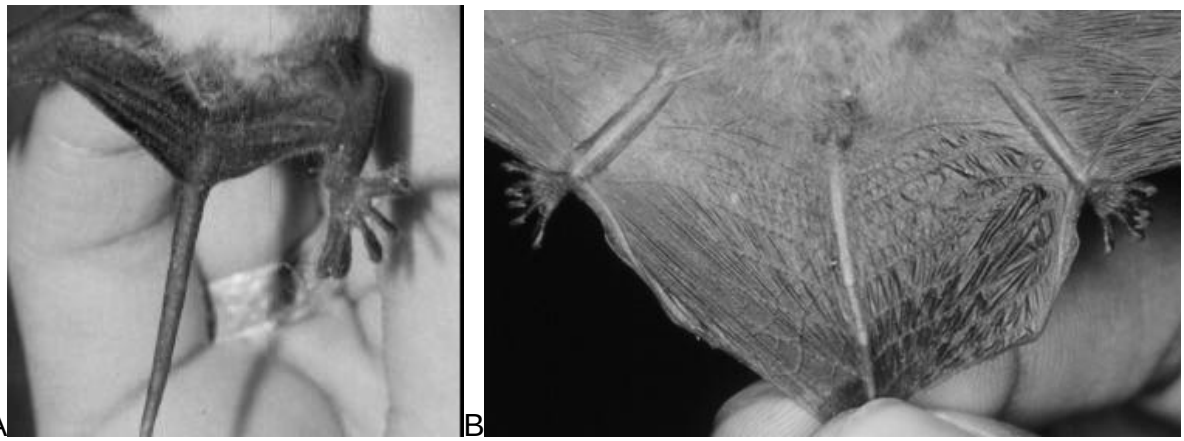


Figure 40 Tail of *Tadarida pumila* (A) and *Eptesicus/Pipistrellus* (B)

11.
second phalanx of 3rd digit about three times as long as the first digit; braincase high and rounded. 3rd and 4th fingers are bent at the joint between the 1st and 2nd phalanx when at rest [Fig 41] (all these and no postcalcarial lobe) (12)

second phalanx of third digit not especially elongated (15)

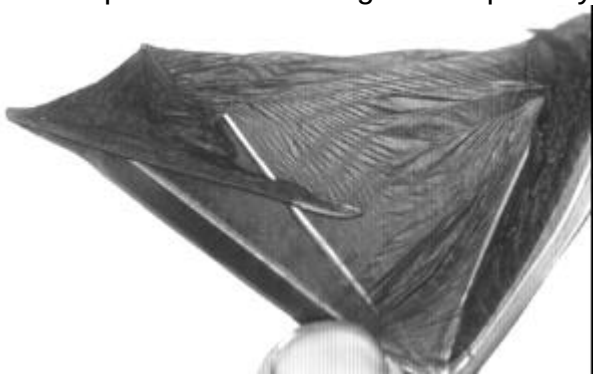


Figure 41. Wing of *Miniopterus* showing elongated second phalanx of 3rd digit

12.
Forearm measurement more than 46 mm (mean = 48.4; 46.7-49.9); greater length of head exceeding 16.0 mm. *Miniopterus gleni*

In general, forearm less than 46 mm; greater length of head smaller than 16.0 mm (13)

13.
Forearm more than 40 mm (14)

Forearm less than 40 mm. *Miniopterus manavi* (May be a form of *Miniopterus minor*)

14. (Note: The presence of *M. fraterculus* has not been confirmed)

Greater length of skull is not less than 15 mm (mean = 15.5; 15.0 – 16.1). Forearm mean = 44.2 (41.8-46.6); M3-M3: mean = 6.5 (6.3-6.8). *Miniopterus majori*

Greater length of skull is in general less than 15 mm (mean = 14.8; 14.5-15.1). Forearm mean = 42.8 (40.7-44.4); M3-M3: mean = 5.9 (5.7-6.0). *Miniopterus fraterculus*

15.
Post-calcarial lobe present [Fig. 42A]. Tragus short, curved, and rounded at tip and may be bent forward (16)
No postcalcarial lobe. Tragus long and sharp.[Fig. 42B] *Myotis goudoti*

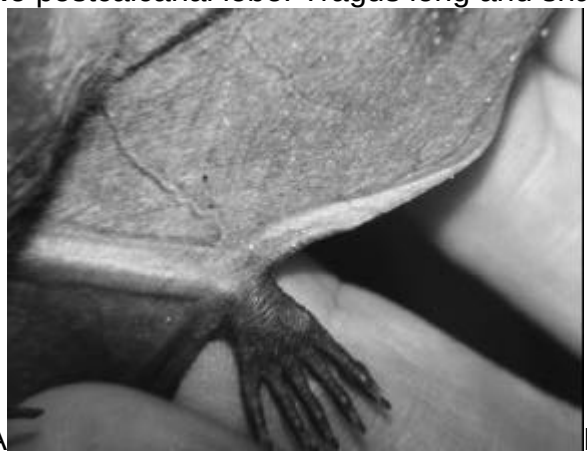
A  B 

Figure 42. Post-calcarial lobe of *Scotophilus* (A); tragus of *Myotis* (B)

16.
Tragus obviously bent forward [Fig. 43] (20)

Tragus not bent forward at top. (17)


Figure 43. Tragus of *Scotophilus*

17.

Last tail vertebrae projects beyond membrane by a maximum of 1mm. The post-calcarial lobe broad with visible T-piece cartilage. Two pairs of upper premolars present (18)

Last 1-2 tail vertebrae project beyond membrane 4-5mm. Post-calcarial lobe is narrow, usually without a visible T-piece cartilage. One pair of upper premolars present. (19)

18.
Note: Pipistrelle species not established as yet – record as Pipistrellus spp. But note any observations.

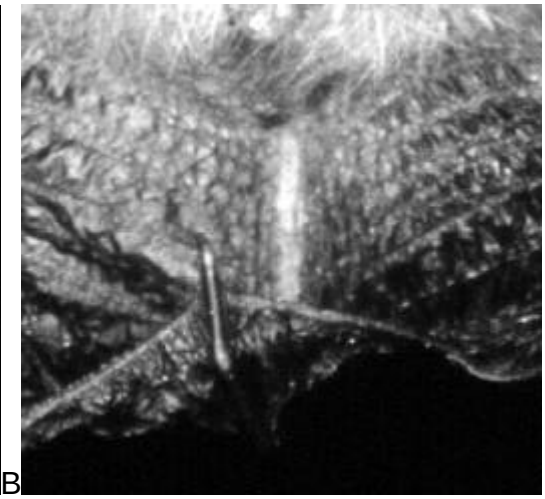
19.
There is no single characteristic that separates these species. See text for further information.

20.
Forearm greater than 55 mm. *Scotophilus robustus*

Forearm less than 55 mm. *Scotophilus borbonicus*

21.
Free terminal proportion of tail emerges above middle of upper surface of interfemoral membrane [Fig. 44B] (22)

Free terminal proportion of tail projecting beyond hind margin of interfemoral membrane [Fig. 44A] (23)

A  B 
Figure 44. Tails of *Tadarida* and *Eptesicus*/*Pipistrellus*

22.
Forearm > 50 mm (58-64); males with large gular sac in the throat. *Taphozous mauritianus*

Forearm < 50 mm (37-41mm); no gular sac. Emballonura atrata

23.
Ears very large (28-40 mm), joined on extended snout; forearm > 60 mm. *Otomops madagascariensis*

Different face (24)


Figure 45. Head of *Otomops*

24.
Ears separated at the base [Fig. 46B] (25)

Ears joined at the base [Fig. 46A]

A  B 
Figure 46. Ears joined (*Tadarida (Mops) leucostigma*) (A) and not joined (*M. jugularis*) (B).

25.
Ears separated at the base. Translucent ears are erect and well separated by a space at the base. Unwrinkled lips. White underside. Forearm less than 45 mm (26)

Ears separated at the base. Forearm is greater than 55 mm. *Tadarida (Tadarida) fulminans*

26.
Ears with anterior margin slightly emarginated below pointed tip. *Tadarida (Mormopterus) acetabulosa* !

Ears without emargination, tips broadly rounded. *Tadarida (Mormopterus) jugularis*

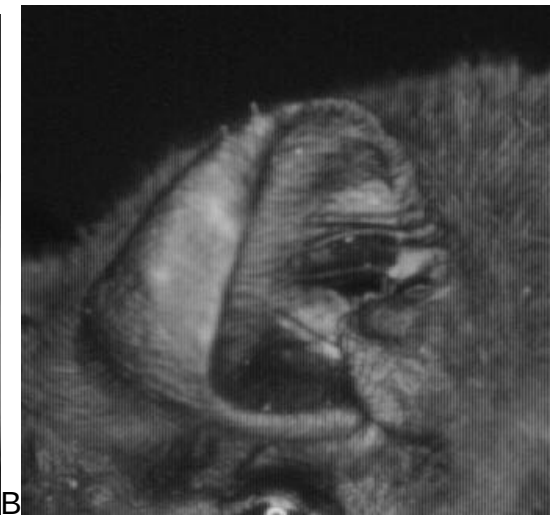

Figure 47. Mormopterus jugularis

27.
Forearm less than 40 mm (28)

Forearm greater than 40 mm (29)

28.
Forearm usually less than 38mm; Tragus is small and square. Tadarida (Chaerephon) leucogaster [Fig. 48A]

Forearm usually greater than 38mm; Tragus is small, sharp and straight. Tadarida (Chaerephon) pumila [Fig. 48B]

A  B 
Figure 48. Ears of *T. (Chaerephon) leucogaster* (A) and *T. pumila* (B)

29.
Forearm greater than 55mm. *Tadarida (Mops) midas miarensis*

Forearm less than 50 mm. *Tadarida (Mops) leucostigma*

Box 1: KEY to the Vespertilionidae

1.
Post-calcarial lobe. Tragus short, curved, rounded at tip or mushroom shaped. *Pipistrellus, Eptesicus, Scotophilus* (2)

No postcalcarial lobe. *Miniopterus, Myotis* (3)

2.
Last tail vertebrae projects beyond membrane max. 1mm. Post-calcarial lobe broad with visible T-piece cartilage. Tragus not mushroom-shaped at top. *Pipistrellus*

Last 1-2 tail vertebrae project beyond membrane 4-5 mm; post-calcarial lobe narrow, usually without visible T-piece cartilage. Tragus mushroom-shaped at top (check!!). Two upper incisors on both sides. *Eptesicus*

Tragus mushroom shaped at top. One incisor on each side. *Scotophilus*

3.
Second phalange of the 3rd digit is practically three times longer than the 1st phalange (2nd bone of the longest finger is about 3 times that of the first bone.). Domed forehead. Very small, triangular ears which do not project above the top of the head. 3rd and 4th fingers are bent at the joint between the 1st and 2nd phalanx when at rest. *Miniopterus*

Ears always longer than broad, project over top of head. Tragus lancet-shaped, more or less tapering to a point. *Myotis*

Box 2: KEY to the Miniopterus

1.
Forearm measurement more than 46 mm (mean = 48.4; 46.7-49.9); greater length of head exceeding 16.0 mm. *M. gleni*

In general, forearm less than 46 mm; greater length of head smaller than 16.0 mm (2)

2.
Forearm more than 40 mm (3)

Forearm less than 40 mm. *M. manavi*

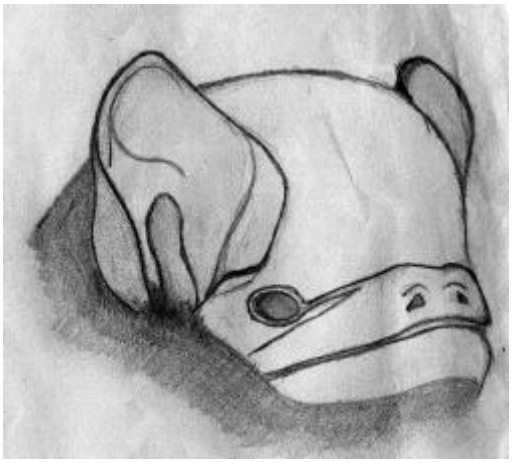


Figure 49. Miniopterus manavi

3
Greater length of skull is not less than 15 mm (mean = 15.5; 15.0 – 16.1). Forearm mean = 44.2 (41.8-46.6); M3-M3: mean = 6.5 (6.3-6.8). *M. majori*

Greater length of skull is in general less than 15 mm (mean = 14.8; 14.5-15.1). Forearm mean = 42.8 (40.7-44.4); M3-M3: mean = 5.9 (5.7-6.0). *M. fraterculus*

Box 3: Key to the Molossidae

1.
Ears are erect and well separated by a space at the base (2)

Ears meet at the same point or join on the upper section of the front (3)

2.
Antitragus is low and is wider than long. Unwrinkled lips, medium-thick jaws, a skull with a tall and posteriorly curving coronoid process, shallow basisphenoid pits, and a well developed 3rd upper molar tooth. *Mormopterus*

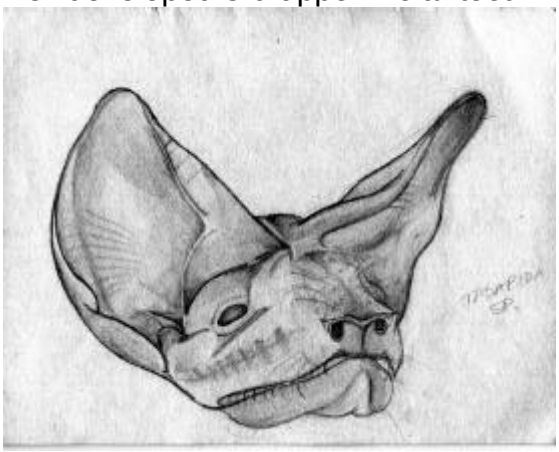
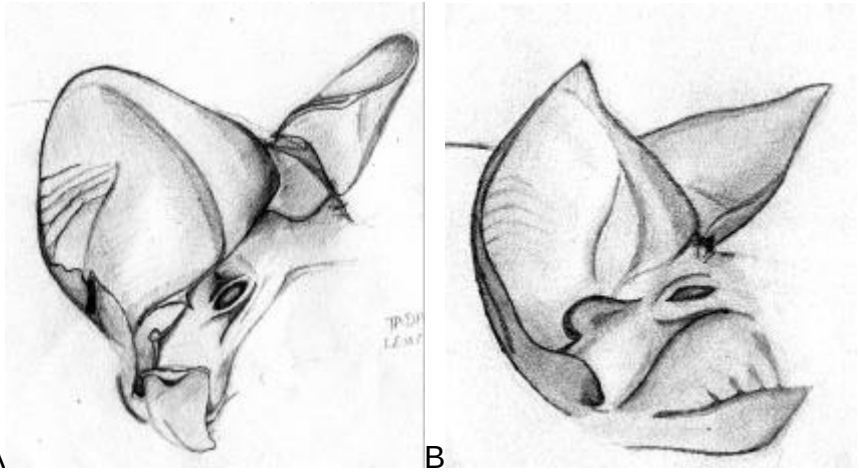


Figure 50. *Mormopterus jugularis*

3.
Ears are long, joined at the base; no antitragus, basisphenoid pits are very pronounced. Series of small spines along the anterior body of the ears. The ears, 25-40 mm in length are joined by a low membrane. A glandular sac is sometimes located in the lower throat region. *Otomops*

Ears, basisphenoid pits are different. Antitragus is relatively big; basisphenoid pits are well developed but the body and form are variable; Wrinkled lips, deep anterior palatal emargination, relatively thin jaws and a 3rd upper molar with a pronounced N-shaped occlusal pattern. *Tadarida* (4)



A B

Figure 51. *T. (Chaerephon) leucogaster* (A) and unidentified *Tadarida sp*. (B)

4.
Ears joined over top of head by a band of skin, very wrinkled lips, a robust skull, medium to thick jaws, a last upper molar that is reduced to a V pattern, and usually two lower incisors on both sides. From Tadarida and Chaerephon, it is distinguished by having more developed sagittal and lambdoidal crests in the skull, a generally thicker dentary with a higher coronoid process, usually more palatal emargination, and reduced dentition. *Mops*

Chaerephon differs from Tadarida in that the ears joined by a band of skin, usually a more elevated mandibular condyle, and broader wing tips. Differs from Mops in having less robust jaws and more constricted anterior palatal emargination. There are usually 5 upper cheek teeth and the last molar has an N-shaped occlusal surface. *Chaerephon*

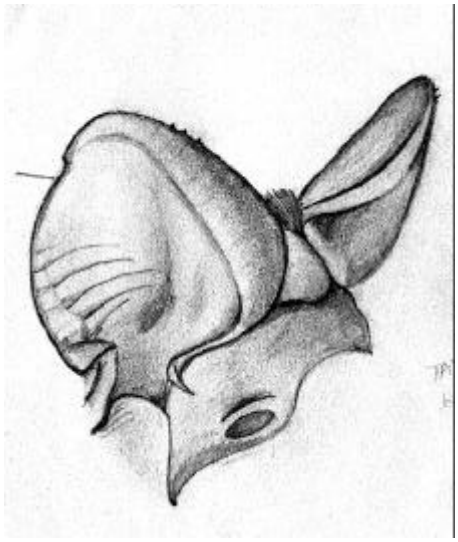


Figure 52. *Tadarida (Chaerephon) leucogaster*

A Working Identification Guide to the Bats of Madagascar!

"This is excellent - a real leap forward in bat work in Madagascar…..". **Professor Paul Racey.**

ISBN 0-9526632-8-7