Hunting of endemic *Rousettus* fruit bats in Madagascar: the demand for bushmeat, the impact on bat populations and the socioeconomic setting

Andoniaina Radosoa Andrianaivoarivelo

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MADAGASIKARA VOAKAJY

3. Contact Details

Address B. P. 5181, Antananarivo

Rousettus madgascariensis

INTRODUCTION

Rousettus madagascariensis is the smallest of the three frugivorous bats (*Pteropus rufus*; *Eidolon dupreanum*) species all endemics to Madagascar, it is widespread especially in the coastal lowland but rare and absent in the central highlands and the south-west region (MacKinnon *et al.* 2003; Goodman *et al*. 2005). The main threats to *R. madagascariensis* include hunting pressure at roosts (Jenkins *et al*. 2007; Rakotonandrasana and Goodman 2007; Jenkins and Racey 2008) in sites that are not inside protected areas (Goodman *et al*. 2005) or considered sacred (Rakotoarivelo and Randrianandriananina 2007).
Flight allows *R. madagascariensis* to cover large distances in a short period of time and to cross various types of landscapes, which could constitute physical barriers for other families of mammals (Norberg & Rayner 1987; Arita & Fenton 1997; Bachmann *et al*. 2000), and for this reason they are considered key species on islands with depauparate frugivore communities.

Rousettus madagascariensis is restricted to the island of Madagascar, approximately 1,580 km long and 570 km wide. The species range and distribution encompasses both the east and the west in association with forested areas and caves (Pont & Armstrong 1990; Goodman 1998, 1999).

R. madagascariensis is smaller, weighing from 50-80 g with a total length of 11.5-14.4 cm, a forearm of 6.5-7.5 cm, and a wingspan of 42.5-52.0 cm. Living in colonies that vary from hundreds to several thousand animals, *R. madagascariensis* dwell in natural caves which are relatively dark and humid (MacKinnon et al. 2003; Cardiff 2006). Although this species is able to survive in degraded areas by feeding on introduced and cultivated fruits (Goodman et al. 2005; Goodman 1999; Andrianaivoarvivelo et al. 2007), its conservation status is classed as Near Threatened because of high hunting pressure and degradation of native forest vegetation in and around foraging and roosting sites (Andriafidison et al. 2008).

It appears to be hunted exclusively for subsistence and bats are harvested as being knocked down from the cave ceiling with wooden batons (Rakotonandrasana and Goodman 2007). The ecology of this species has been studied over the last ten years in Madagascar, but attempt has not yet conducted to periodically monitor bat roosts to investigate the population trend in response to human predation at roost. I investigated here the threat of *R. madagascariensis* population and their movement across distant roosts in order to create vital information with which I could create realistic conservation plans. The objectives of this study were to assess hunting to the bat colonies, and investigating the survival of the population in a single cave. The results of the study would contribute to create a strategic sustainable management of the bat colony and improve the social contract that local people could use for this concern.

METHODOLOGY

Study site

This study was conducted in four cave roosts, Ambatofotsy, Sahavoa, Ambohimanjaka and Antsahahety in the Tratramarina Tsaravinanay (Sahavoa and Ambohimanjaka) and in the Ampasimaneva Communes respectively in the Anosibe An'Ala District (19°24'-19°32'S and 47°57'-48°19'E) of the Alaotra Mangoro Region. The western part of the district that comprises three of the bat roosts (Sahavoa, Ambohimanjaka and Antsahahety) has retained significant mid-altitude continued humid forest cover and the other roost (Ambatofotsy) is within the Eastern forest block that is isolated from the later forest. The minimum and maximum distance between the roosts are 7km (Ambohimanjaka and Sahavoa) and 38.7km (Ambatofotsy and Ambohimanjaka) respectively. Large areas of land are used for agriculture and slash and burn clearance occurs at the edge of the humid forest. There are no official protected areas in the district. But the Ambatofotsy and Sahavoa studied roosts were within the new protected forest areas which have received provisional conservation status in September 2008 from the Ministry of Environment and Forest of Madagascar.
The remaining native vegetation in Anosibe An'Ala is of the lowland forest ecoregion (Humbert and Cours Darne 1965), the natural forest areas are suffering from slash-and-burn agriculture and encroachment. The climate in the study area is subdivided into distinct wet and dry seasons, Donque (1972) illustrated rainfall in this domain varies from a monthly peak of 500 mm in March to a minimum of 100 mm in October.

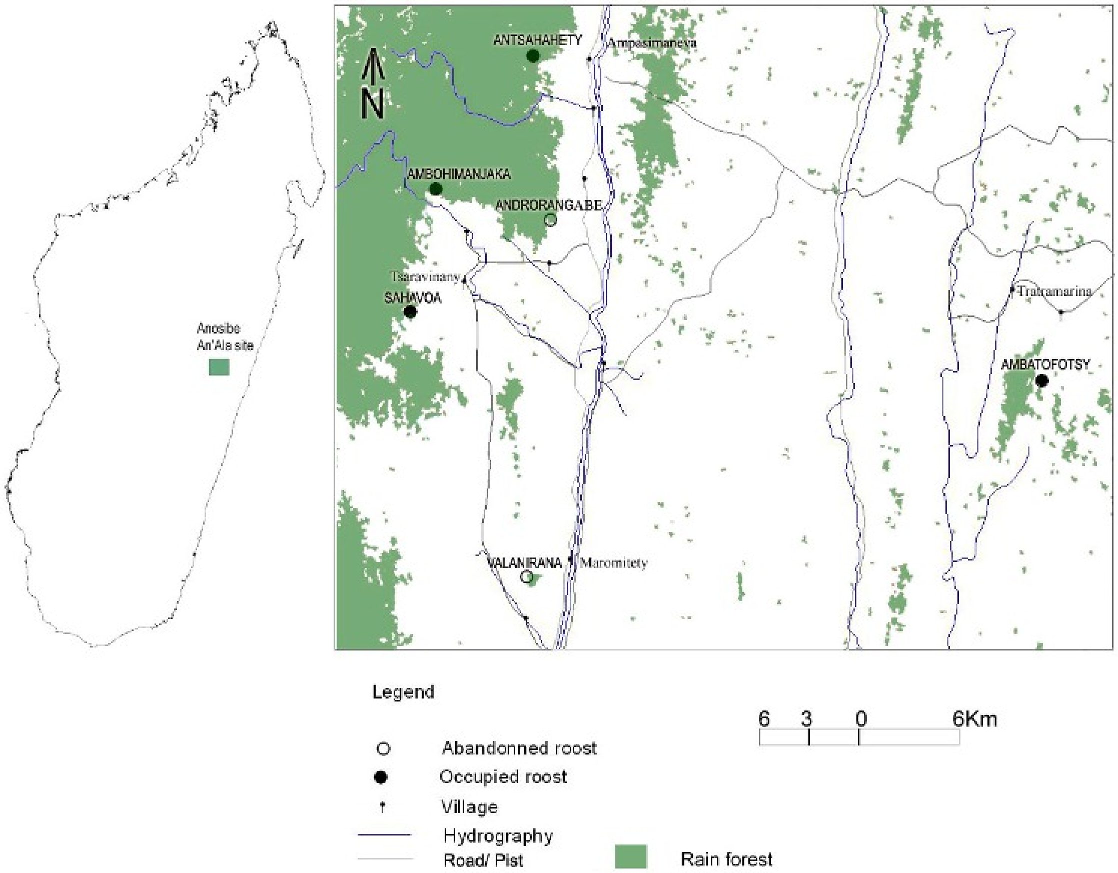

Figure 1: The four studied *Rousettus madaagscariensis* cave roosts in the Anosibe An'Ala District.

Interview about *R. madagascariensis* hunting at roost (described on the proposal)

This was undertaken before I started the roost-based research. People living beside the cave and who actually were our local guides were asked about who was hunting the bats, where do people hunt bats and how, whether they were sold or used for subsistence, the frequency of hunting, the numbers of bats hunted and any effects due to season. I also tested whether the people know that hunting and eating bats is legal between May and September.

Hunting assessment at the cave roosts

The presence of dead bats or wood sticks being used to wave the bats and hunt them were assessed for every roost and every of the five capture sessions. The evidence of torch the hunters used to illuminate the dark cave was also noticed.
Colony size for every session and in each cave was assessed by extrapolation or counted from the number of bright eyes taken from a digital camera.

Capture and marking

Mist nets (2 x 6 m, 1 X 6m, 1 X 6m and 1 X 9m, 1 X 6m in Ambatofotsy, Sahavoa, Ambohimanjaka and Antsahahety roosts respectively) were erected on the spaced areas in the entrance of each of the four roosts before the bats emerged the roost. We were unable to install mist nets at some of the entrances in the same roost (Ambohimanjaka) because of the presence of the hazardous rocks and the risk of personal injury. A part from the main entrance of the cave, there are some small crevices in the ceiling (Ambatofotsy, Ambohimanjaka and Antsahahety), which obviously allow bats to move in and out, but the exact locations of these bat passages could not be always seen from the interior of the cave. Five missions A, B, C, D, E, (A: Nov-Dec 08; B Feb-Mar09; C June-Jul 09 (C); D Oct-Nov 09; and E Jan-Feb 10) were made during the study, one capture per roost were conducted in each cave during A and B missions. But we increased the capture number to five nights per roost to maximize the recapture records in the next sessions. Thus, the bats were captured during five consecutive nights for each of the D and E sessions in Ambatofotsy, and for each of the C, D and E sessions in Sahavoa and Antsahahety.
Because of the hazardousness of the Ambohimanjaka roost, only one capture per session was conducted in the A, B and C sessions.
Mist nets were opened before 18:30 during our five A, B, C, D, E captures sessions between November 08 and March 10 (A: November-December2008, B: February –March 2009, C: June-July 2009, D: October-November 2009, E: January and February 2010) and closed at 20:00 when bats were emerged. They were kept individually in a clothing bag, sexed, marked and released in soon in the same night. The number of capture in every capture session and cave roost was presented in the table 1.

They were sexed by observing the evidence of penis or a single underarm pair of mammary glands (Racey 1988). Bat weighing less than 50 g or with unfused phalangeal epiphises cartilages in finger bones (Anthony 1988) were classed as juvenile. Females with adult weight (more than 50g) but with less apparent mammary gland were ranked as sub adult and adult females were classed as lactating, pregnant, parous or nulliparous (Racey 1988) and parturition.

Table 1: bat capture periods (closed cells) in the four roost sites and during the five missions (A: Nov-Dec 08, B: Feb-Mar 09, C: June-Jul 09, D: Oct-Nov 09, E: Jan-Feb 10). the individual marking tags we used were "cb": chained ball necklace with coded ring; "tb": thumb band with code; "et": ear tag with code; "et+cb": one ear tag and one chain ball necklace with coded ring were attached to one bat and "cb/tb": chain ball necklace with coded ring and coded thumb band was attached to some of the bats. The number one to five represented the rank of night capture per capture session. Grey shaded cells indicated that capture was conducted.

Roost Site	Nov-Dec 08 (A)		Feb-Mar 09 (B)	June-Jul 09 (C) 5 successive capture nights					Oct-Nov 09 (D) 5 successive capture nights					Jan-Feb 10 (E) 5 successive capture nights				
Sub session	1 A	2 A	1B	1C	2C	3C	4C	5C	1D	2D	3 D	4 D	5 D	1 E	2 E	3 E	4 E	5E
Ambohimanjaka	cb		tb	et														
Ambatofotsy	cb		tb	et					et					et				
Antsahahety	cb		tb	et/cb					et					et				
Sahavoa	cb		cb/tb	et+cb					et					et				

Female bat was classed as nulliparous or sub adult female if it has never given birth to a pup and considered as parous if it has given birth to an offspring and breastfed once at least, this was seen through the developed mammary glands but without milk. Bat was considered lactating if did not carry pup but the nipple still produced milk. Bat was pregnant if the foetus in the bat's abdomen could be felt by the fingers. And bat was carrying their young if the new born is trapped with it.

To individually identify bat during the recapture session and to test the effectiveness of any of the following marking techniques, adult bats were individually marked with three marking tag types with code (detailed in the above table 1) such as chain ball necklace with ring attached to the bat's neck or ear tag attached to the bat's ear or thumb band fixed to the right thumb (REF). Bats recaptured in the cave and with previous tags were examined closely to check the band number (Bauerova et al. 1989).
Juvenile bats were not ringed but additional brown dye fur was applied for either adult or juvenile bat, thus the fur region we coloured depended on the capture site, bats were marked dorsally on the bottom, on the right side, left side and the top of the head for Ambatofotsy, Ambohimanjaka, Antsahahety and Sahavoa roosts respectively.

Mark analysis

Program MARK2 was used to estimate the survival (White & Burnham 1999) of *Rousettus madagascariensis*. It allows estimation of survival rates and population size by operating a serie of statistical models to mark-recapture data. Marked animals were investigated as they could be individually marked and be re-encountered live. Mark-recapture in this studies was used for open populations as bats can fly and move to a different roosts and for this reason we used the open model of Cormack-Jolly-Seber (CJS).
Results from this mark-recapture study, analysed using program MARK, can help assess survival rates and population trends over time in *R. madagascariensis*, so that managers can respond and management of the population adapted appropriately.
This analysis include the Akaike.s Information Criterion (AICc) corrected for small sample sizes was used to measure the goodness of fit of an estimated model. A model represented

the interaction between parameters such as Capture (P), Recapture (P) rates or population size or survival.
(Burnham & Anderson 1998), which MARK does automatically. The Delta AICc is the difference between the model with the lowest AICc and the current model and is used to rank models. If the difference between the model with the lowest AICc and the alternative model is less than 2, then both results from models are acceptable. A difference greater than 2 but less than 7 indicates some support for a difference between the models, but difference greater than 7 shows that the
models are different (Cooch & White 2001). The factors we used in this study were the sex (males and females) and the five captures sessions.

RESULTS

Interview to people and hunting in the roost

None of the interviewed persons (local guides, village leaders and restaurant holders) knew about people hunting bats in our study roosts and we did not see any evidence of alive or dead bats sold or hunted in the nearby villages.
However, evidence of hunting was observed at some of the visited cave (Figure 2),

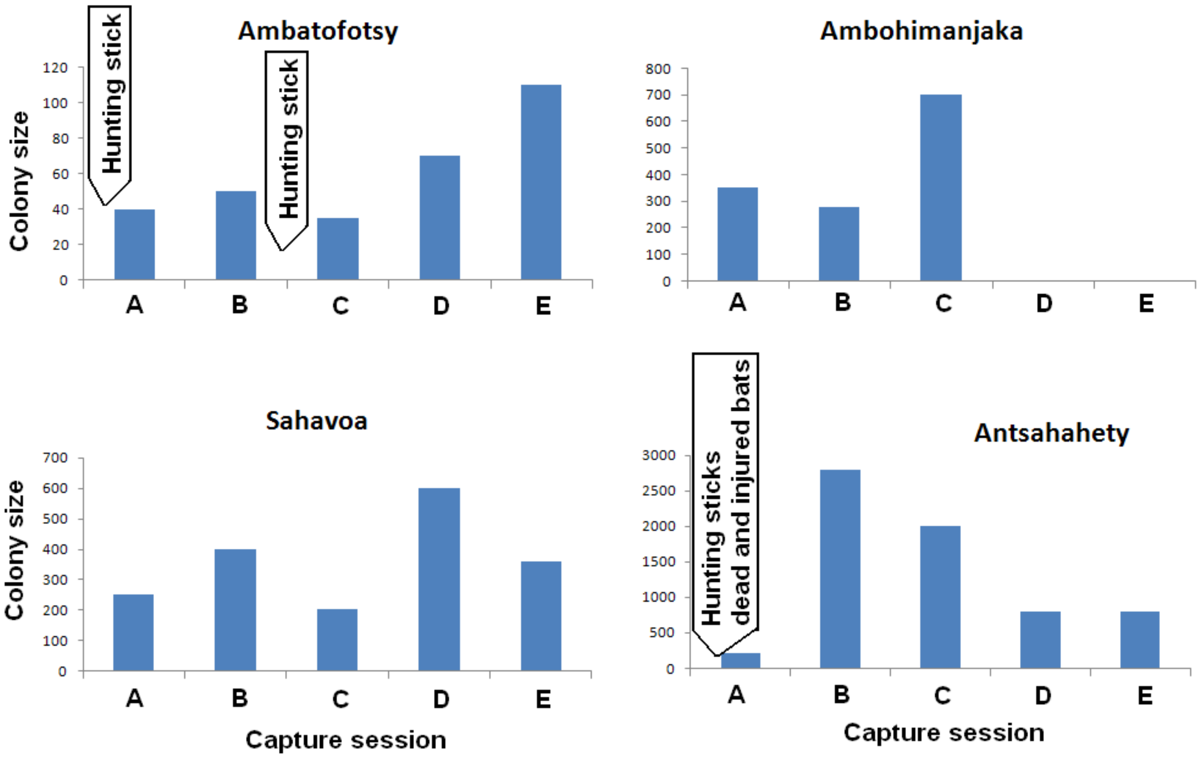

Figure 2: colony size and hunting evidence found in the four caves per capture session.

Torch and waving sticks were seen at the Ambatofotsy roost in A and B sessions (Dec 08 and July 09) and dead and injured bats accompagned with waving stick served to hit the bats were found in Antsahahety. We noticed that the bat population decreased after hunting event and hunters intervened either during the hunting season or not. Hunting may temporary caused bats to abandon their roost; such was the case of those in Antsahahety in December 2008 (Figure 2).

Capture and marking

The number of captured bats was 1751 (number of capture occasions), the total number of tagged bats was 1273 (Table3) and the recapture occasions in whole caves was 17,67%, the highest recapture rate was in the Sahavoa cave.

Table 1: Five capture sessions: with tagged and non tagged bats in the four study caves

Session	Total	With Tag				Without Tag			
		Ambatofotsy	Ambohimanjaka	Antsahahety	Sahavoa	Ambatofotsy	Ambohimanjaka	Antsahahety	Sahavoa
A (Nov-Dec 08)	89	10	15	29	31	0	2	0	2
B (Feb-Mar 09)	107	19	25	26	19	1	6	10	1
C (Jun-Jul 09)	474	19	48	134	81	3	5	161	23
D (Oct-Nov 09)	629	45	-	379	205	0	0	0	0
E (Jan-Feb 10)	452	98	-	287	56	0	0	9	2
Total	1751	191	88	855	392	4	13	180	28

Table 2: Number of ringed bats in each of the four caves

Site	Total	Ambatofotsy	Ambohimanjaka	Antsahahety	Sahavoa
First capture (Number of records)	1273	169	84	725	295
Recapture occasion: in the same roost (percent of ringed bats)	225 (17.67%)	19 (11.24%)	0 (0%)	122 (16.82%)	84 (28.47%)
Recaptured: bats from different roosts (bat movements)	28 (4 Females)	3	4	8	13
Total	1526	191	88	855	392

Social structures

- Pregnancy occurred in October and November (2009) as 102 over 108 pregnant bats (total pregnant bats during the five sessions) were captures during this session (Table 3).
- Females bats carried their offspring in January and February (rain season), thus over 74 captured females 65 carried their youngs in this session. Female bats gave birth to a single young in summer.
- Most of the lactating bats were captured in January and February (2010) and some in June and July (2009) but none was captured in October and November (2009).
- The young bat started to fly when they were 23g (the lightest captured in Sahavoa roost July 2009), number of juvenile bats (Weight = 31.21±3.61g, N=61) were captured in June and July 09 but none in January (2010) February (2009 and 2010) and March (2009), indicating that weaning may start before June (Table 4). Individual juvenile weights were significantly different (One sample t-test, DF=32, t-value=

48.048, P<0.0001) to adult weight but male and female juvenile weights were similar (ANOVA, F test, F-value= 1.466, P=0.4666). of the 61 captured juvenile bats 69% were females.

Our research shows the study population of bat is divided into four distinct social groups: breeding males and females (adult, pregnant, breeding female carrying their young), sub-adult or non breeding females and juveniles (males and females).

Table 3: Breeding status of the captured bats in the four roost sites within the five capture sessions (A, B, C, D, E).

Sex	Total	Female					Male				
Session		A	B	C	D	E	A	B	C	D	E
Adult	1161	0	0	0	0	0	78	59	338	371	315
Juvenile (Juv)	61	0	0	25	6	11	0	0	18	0	1
Lactating (Lac)	23	1	3	7	0	12	0	0	0	0	0
Sub Adult (NP)	59	4	14	12	24	5	0	0	0	0	0
Parous (Par)	265	0	27	66	126	42	0	0	0	0	0
Pregnant (Preg)	108	4	1	4	102	1	0	0	0	0	0
With pup (Wpu)	74	2	2	5	0	65	0	0	0	0	0
Total	1751	11	47	119	258	136	78	59	356	371	316

Table 4: Breeding status of the female captured bats in each of the four roost sites within the five capture sessions (A, B, C, D, E). Annotations: Juv: Juvenile; Lac: Lactating; NP: Nulliparous (Sub adult); Par: Parous; Pre: Pregnant; Wpu: With pup.

	Ambatofotsy					Ambohimanjaka					Antsahahety					Sahavoa				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Juv	0	0	11	0	0	0	0	12	-	-	0	0	19	4	13	0	0	35	0	0
Lac	0	43	0	20	16	0	0	0	-	-	0	0	0	0	6	13	0	24	0	10
NP	0	29	0	80	0	100	64	6	-	-	0	19	16	9	6	37	13	3	8	0
Par	0	28	78	0	0	0	27	82	-	-	0	81	62	44	37	0	63	31	53	90
Pre	0	0	0	0	0	0	0	0	-	-	0	0	0	43	1	50	12	0	39	0
Wpu	100	0	11	0	84	0	9	0	-	-	0	0	3	0	37	0	12	7	0	0

Movement between roosts

The 28 recaptured individuals were from different roosts, four of which were females. There was no specific fly because we found in each roost individual(s) from any of the three roosts. The distance travelled by the bats or between roosts varied from 7 to 38.5km. the most distant flight path was between the Sahavoa and Ambatofotsy roosts (38.5km) but we could not assumed that they travel from one cave to another in a single night.

Moreover, we found the evidence that three males and one female moved to different roosts at a different season.

Mark-Recapture analysis

Survival estimate of bats taking into account the two social groups (Males and females: adults and sub adults)and Recapture only model in Mark Program.

The five consecutive night captures for each of the three sessions (C, D, E) data were pooled and the best model was choiced regarding the Delta AICc value with fewest parameter used and without overestimated parameter values (eg. Capture, recapture or colony size estimates, Figure 5).

The results from A (Nov-Dec 08), B (Feb-Mar 09), C (Jun-Jul 09), D (Oct-Nov 09) and E (Jan-Feb 10) missions were presented below. The Phi (or ø) and P notations represented the survival and capture estimates respectively.

The model {Phi(.)P(.)} (Figure 1) fit the best or with low Delta AICc value and fewer parameter in our three study sites (Sahavoa, Antsahahety and Ambatofotsy). The figure demonstrated a survival estimate between two capture sessions (three months) average less than 30%. However the uncertainty in these estimates was extremely large as seen on the Figure 1 especially for bats in Ambatofotsy. The capture estimates were quiet low, which were the same for both sexes for bats either in Sahavoa or Antsahahety with reasonable error bars but with large confidence interval in Ambatofotsy. Even though a best value of AICc was used here, because of the large confidence interval a goodness-of-fit test need to be run to check if whether or not the global model explains the data accurately.

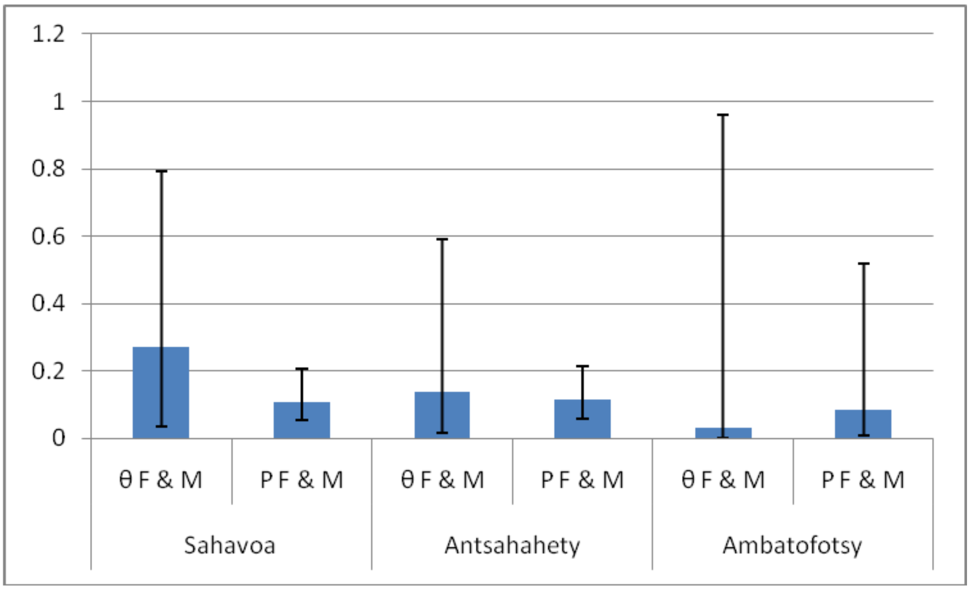

Figure 3: graph from MARK showing survival rates of bats in the Sahavoa, Antsahahety and Ambatofotsy roosts (five sessions within 15 months) at interval confidence of 95%. This is the global model {Phi(.)P(.)}, in this case the model suggested that survival (phi or ø) and capture (p) do not change with sex female (F) and male (M). Delta AICc= 1.1293, 0.6462 and 3.4157 for Sahavoa, Antsahahety and Ambatofotsy population respectively.

Capture (P), Recapture (C) and colony size (N) estimates with the closed capture Model

Bat colony in Sahavoa roost

The model {P(sex)=C(sex)N(sex)} was used, fitted the best (low Delta AICc value) for Sahavoa bat colony in the C session this suggests that the capture and recapture rate were similar for every sex but population size estimate was different to capture and recapture estimates and male and female For D and E sessions at the Sahavoa roosts, the model {P(sex)C(sex)N(sex)} was used, this model revealed that the capture and recapture rates were independant from each other.

In D session the figure 2 showed that the male bats had significantly high capture estimate compared to the female ones but their recapture estimates became lower than that of females suggesting that they were able to avoid being captured again after the first capture, this could be because most of the females were carrying pup which increased their wing loading making them possibily easy to trap, this would not affect the capture probability because both sex did not expect the net at first capture. There was no significant difference between capture or recapture between sex in E session. In E and D sessions the female population size was higher than that of males, which was not the case in session C (dry season).

Bat colony in Antsahahety roost

The model {P(sex)C(sex)N(sex)} was used in the three sessions (C, D, E) in Antsahahety, we found the same result as in Sahavoa (D session) in Antsahahety during C and D, thus the males had higher capture but lower recapture estimates than females this maybe caused by the number pregnant females less able to avoid the net in the next captures in November and males that were able to avoid being recaptured compared to the those females (Figure 5). There was no significant difference between males and females for either capture or recaptures estimates at E session (Figure 5). The estimate population size was significantly higher for females for every one of the three sessions and female population size increases in D session while many bats were pregnants (Figure 6).

Bat colony in Ambatofotsy roost

The model {P(F=M)C(F=M)N(sex)} fitted to the analysis at D session, this model suggested that the capture or recapture estimates were the same for both sex and the colony size estimates were different for females and males. And the same model as in Antsahahety {P(sex)C(sex)N(sex)} was used at E session. There was no significant difference at all for any of the parameters (P; C; N) between sex at D and E season. The data in this site and at the D and E session may suffered from few recaptured individuals or a googness-of fit test shoul be computed to assess the effectiveness of the model used and to choose the most effective analysis to run.

We could conclude that, the model being choosed vary from site to another and from period of capture to another as a consequence of probabily that some roosts were selected by the bat as breeding roosts. The choose of a reasonable model may also be affected by the lack of captured or recaptured individuals which influenced the analysis results, for this fact we aim to visit again the bat roosts and capture more bats to obtain reasonable mark-recapture analysis .

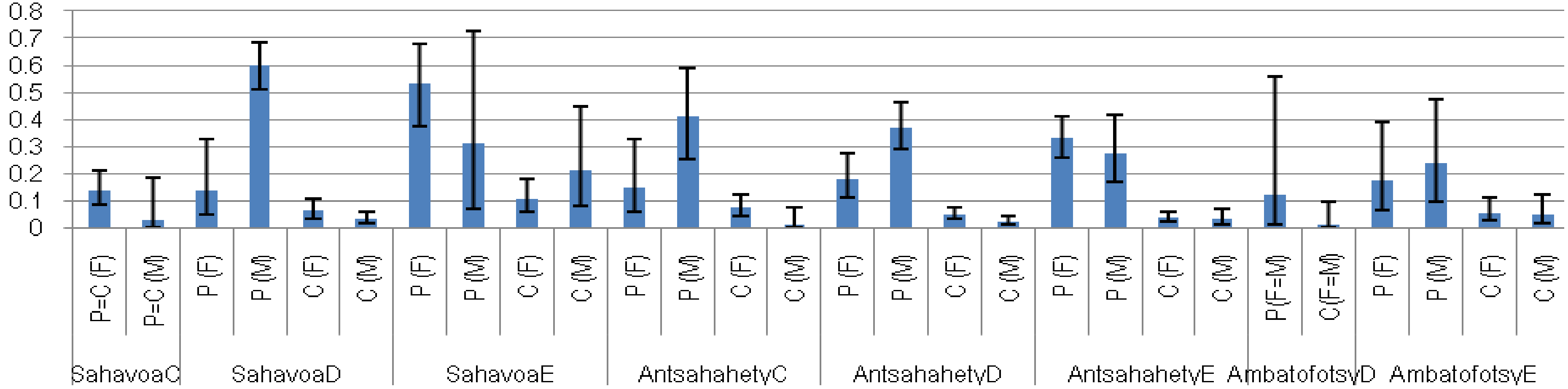

Figure 4: capture and recapture estimates in the four study population, with interval confidence at 95%. The values of Delta AICc in the four population were as follow; Sahavoa C: 3.7484, Sahavoa D:0, Sahavoa E: 5.0628, Antsahahety C: 0, Antsahahety D: 0 and Antsahahety E: 3.4157

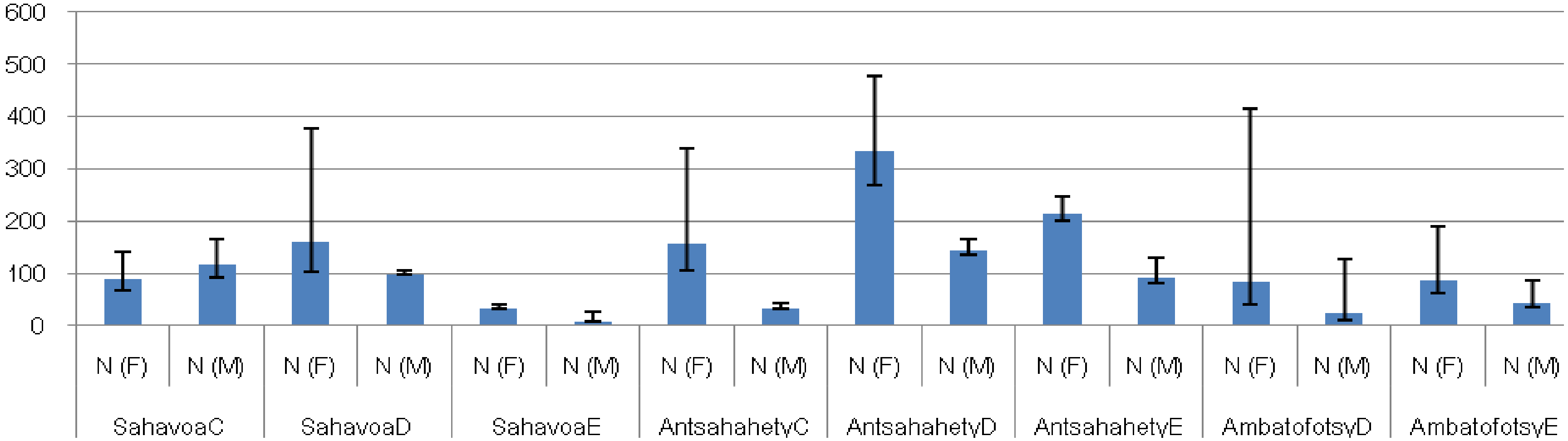

Figure 5: Population size estimate of both sex in the four study roosts with 95% interval confidence in the five capture sessions.

Conclusion

Bats in our four study sites were hunted during any season of the year, but we found no evidence of bat meat in the village. Bats may temporary abandon cave in response to hunting but the extend to which bats tolerate heavy and continuous hunting need more investigation. Bats would not feel save if they are disturbed in the day as there is not always available temporary roosts to escape from human predation and they are vulnerable to predator while flying in the daylight. Much attention need to be taken for roosts used as breeding roosts (maternity roosts), and local villagers need to be aware about those roosts as well as the reproduction season of bats. Hunters likely caused stress to roosting breeding bats (with pups or lactating) and they could be also at higher risk because a maternity roost may hold several individuals from several roosts, they hardly are able to escape from hunters.

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