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This is the **accepted version** of the journal article:

Rocha, Ricardo; Fernández-Llamazares, Álvaro; López-Baucells, Adrià; [et al.].  
«Human-bat interactions in rural Southwestern Madagascar through a biocultural  
lens». *Journal of Ethnobiology*, Vol. 41, issue 1 (March 2021), p. 53-69. 17 pàg.  
DOI 10.2993/0278-0771-41.1.53

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This version is available at <https://ddd.uab.cat/record/292505>

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**Author Accepted Manuscript of the paper:**

Rocha, R., Fernández-Llamazares, Á., López-Baucells, A., Andriamitandrina, S.F.M., Andriatafika, Z.E., Temba, E.M., Torrent, L., Burgas, D., Cabeza, M. (2021) Human-Bat Interactions in Rural Southwestern Madagascar through a Biocultural Lens. *Journal of Ethnobiology*, 41(1): 53–69. doi: [10.2993/0278-0771-41.1.53](https://doi.org/10.2993/0278-0771-41.1.53)

**Human-bat interactions in rural southwestern Madagascar from a biocultural lens**

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## **Abstract**

Human-bat interactions are common in rural areas across the tropics. Over 40 bat species occur in Madagascar, most of which are endemic. Forest loss is changing the distribution of bats throughout the island, with potential increases in both the abundance of synanthropic species and human-bat interactions. We set out to study knowledge of, interactions with, and attitudes towards bats in rural Madagascar, including reports of food and ethnomedicinal uses of bats, their cultural representations in folklore, and the existence of culturally-enforced taboos in relation to them. We administered 108 surveys with open- and closed-ended questions with adults from the Tanala and Betsileo ethnic groups living around Ranomafana National Park. Most interviewees mentioned at least two types of bats. Over 10% of the interviewees had consumed bats and ~20% used bat guano as fertilizer. Around one-fifth recognized cultural taboos inhibiting bat hunting and consumption and most considered bats not to be dangerous. However, some informants mentioned that bats could carry diseases and complained about the bad smell and noise associated with bat roosts in houses and public buildings. Nearly 25% of the respondents could identify cultural representations of bats in local folklore. Malagasy rural communities interact closely with bats, but severely underestimate the diversity of bat species around them. Taken together our results greatly increase the understanding of social -ecological complexities of human-bat relationships in rural Madagascar, offer possible pathways for biocultural approaches to conservation and yield insights applicable to other communities coexisting with bats in across the humid tropics.

**Keywords:** attitudes, *fady*, folklore, human-wildlife interactions, perceptions.

## Introduction

Humans have interacted with bats for millennia (Kingston, 2016; Low et al. 2021). Yet, as anthropogenic impacts change ecosystems globally (Díaz et al. 2019), it becomes increasingly important to identify social and cultural variables associated with human-bat coexistence. Such knowledge can be the foundation for developing effective and culturally-appropriate local conservation strategies that are beneficial to both humans and bats.

Over 1,400 bat species are known to western science (Simmons and Cirranello 2020) and, following a commonly observed biogeographic pattern, bat diversity rises with increasing proximity to the equator and peaks in tropical regions (Altringham 2011). Although many bat species are relatively abundant close to human settlements and some can even be characterized as synanthropic (i.e., as living near and benefiting from humans; López-Baucells et al. 2017; Russo and Ancillotto 2015), recorded ethnobiological knowledge about bat diversity and ecology is somewhat sparse (e.g., da Costa Rego et al. 2015; Lavery et al. 2021; Sexton and Stewart 2007; Sheherazade and Tsang 2015; but see Fleck et al. 2002 and Taylor and Butler 2007), especially considering how widespread, species-rich and often locally abundant bats are. This gap in recorded knowledge is likely in part associated with bats' nocturnal habits and elusive behaviours. Yet, throughout the world, numerous studies on bat ethnobiology have uncovered a wide array of contemporary and historical cultural representations of bats in local folklore, traditional uses and beliefs (Tanalgo et al. 2016; Musila et al. 2018; Lavery and Fasi 2019).

Madagascar is home to a unique combination of fauna that includes ~44 bat species, of which at least 32 (73%) are endemic to the island and >10% are classified as either threatened or near threatened by the IUCN Red List of Threatened Species (Cardiff and Jenkins 2016). Large colonies of molossid bats roost in buildings throughout the country (López-Baucells et al. 2017; Razafindrakoto et al. 2010) and several bat species are often more abundant in humanized areas than forest habitats (Kemp et al. 2019; Rakotoarivelo et al. 2007; Randrianandrianina et al. 2006).

Hunting of bats for bushmeat is widespread across the country, targeting both the island's endemic pteropodids (Jenkins et al. 2011; Randrianandrianina et al. 2010) as well as smaller microchiropterans (Fernández-Llamazares et al. 2018; Goodman 2006; Goodman et al. 2008; Jenkins and Racey 2008). To some Malagasy people, bats are believed to navigate between the physical and spiritual realms (Fernández-Llamazares et al. 2018) and although not widespread, there is some anecdotal evidence of the use of bats for medicinal purposes (Fernández-Llamazares et al. 2018; Jenkins and Racey 2008). At least in some regions, bat guano is commonly collected, used, and traded for fertilizer (Buliga 2010; Fernández-Llamazares et al. 2018) and some bat roosts are visited by cave tourists (Cardiff et al. 2012).

Malagasy culture is deeply intertwined with the natural world and over time has developed a rich and complex system of customary institutions, locally known as *fady* (taboo), to govern the use of natural resources (Golden and Comaroff 2015; Jones et al. 2008; Lingard et al. 2003; Tengö et al. 2007). Yet, a combination of poverty, rapid population growth, insecure land-tenure and multiple interacting anthropogenic threats (e.g., mining, hunting, agricultural expansion, and great demand for timber and charcoal production), pose great challenges to the conservation of the island's remaining biodiversity (Cabeza et al. 2019; Eklund et al. 2016; Irwin et al. 2010; Jones et al. 2019a,b; Rocha et al. 2015). Furthering our understanding of human-wildlife interactions in Madagascar is thus key for the design of evidence-based strategies aimed at averting the decline of biodiversity in what is one of the highest global conservation priorities (Brooks et al. 2006).

We aim to understand human-bat interactions among the Betsileo and Tanala ethnic groups living in rural communities around the periphery of Ranomafana National Park (hereinafter RNP). The park is located in an ecologically unique tropical rainforest in southeastern Madagascar. Understanding local knowledge of bats in this region is important for the development of culturally-appropriate conservation interventions that maximize the benefits from ecosystem services associated with bats, while simultaneously minimize potential human-bat conflicts. Our assessment of knowledge includes uses and attitudes towards bats, the existence of bat-related *fady*, and

mentions of bats in local folklore. This work complements previous studies investigating roost selection by synanthropic bats (Lopez-Baucells et al. 2017) and habitat use and potential ecosystem services provided by bats in the same biocultural landscape (Kemp et al., 2019).

## **Methods**

### **Study Area**

The study was conducted around RNP (21°16'S, 47°20'E, Fig. 1), in the regions of Haute Matsiatra and Vatovavy-Fitovinany southeastern Madagascar. The park, established in 1991, is part of the “*Rainforests of the Atsinanana*” UNESCO World Heritage Site and with ~43,500 ha of continuous humid forest represents one of the largest remaining areas of primary rainforest in the country. RNP is surrounded by >150 villages with a population of more than 50,000 in an area of approximately 500 km<sup>2</sup> (Kari and Korhonen-Kurki 2013). Local communities in the area belong to two self-identified ethnic groups: the Betsileo and the Tanala (Vuola and Pyhälä 2016). The Betsileo inhabit the highlands to the west of RNP and the Tanala inhabit the lowlands to the east. Local communities, like many throughout rural Madagascar, depend primarily on subsistence-based rice farming, cultivated either through slash-and-burn (locally known as *tavy*) or in irrigated paddies. Other local crops include cassava, beans, peanuts, sugarcane, maize, banana and leafy vegetables, which are complemented with forest products, including honey and crayfish (Kari and Korhonen-Kurki 2013).

**Figure 1** - Location of the study area within Madagascar.



Extensive mist-netting and bioacoustic sampling between 2013-2016, augmented with previous observations by Goodman et al. (2018), revealed that at least 14 bat species inhabit RNP and its surrounding agricultural landscapes (Kemp et al. 2019; López-Baucells et al. 2017; Table 1). Multiple species roost in public and private buildings across the study area (López-Baucells et al. 2017).

**Table 1** – Bat species detected in and around RNP. List compiled based on records from López-Baucells et al. (2017), Kemp et al. (2019) and Goodman et al. (2018).

Species (forearm length in mm) <sup>1</sup>	Common name	IUCN threat level <sup>2</sup>	Level of endemism
<i>Eidolon dupreanum</i> (115-131)	Madagascan fruit bat	VU	Madagascar
<i>Pteropus rufus</i> (154-172)	Madagascan flying fox	VU	Madagascar
<i>Rousettus madagascariensis</i> (58-78)	Madagascan rousette	VU	Madagascar
<i>Macronycteris commersoni</i> (80-97)	Commerson's leaf-nosed bat	NT	Madagascar
<i>Paremballonura atrata</i> (37-41)	Peter's sheath-tailed bat	LC	Madagascar
<i>Myzopoda aurita</i> (47-50)	Eastern sucker-footed bat	LC	Madagascar
<i>Chaerephon atsinanana</i> (32-38)	Madagascar free-tailed bat	LC	Madagascar
<i>Mops leucostigma</i> (42-45)	Madagascar white-bellied free-tailed bat	LC	Non-endemic
<i>Mormopterus jugularis</i> (36-39)	Peter's wrinkle-lipped bat	LC	Madagascar
<i>Myotis goudoti</i> (34-41)	Malagasy mouse-eared bat	LC	Madagascar
<i>Neoromicia matroka</i> (29-35)	Malagasy serotine	LC	Madagascar
<i>Scotophilus robustus</i> (60-65)	Robust yellow bat	LC	Madagascar
<i>Miniopterus majori</i> (41-47)	Major's long-fingered bat	LC	Madagascar
<i>Miniopterus manavi</i> (32-39)	Manavi long-fingered bat	LC	Madagascar

<sup>1</sup> Forearm length from Russ et al., 2003; IUCN threat level: LC = Least concern, NT = Near threatened, VU = Vulnerable.

## Data Collection

Between November and December 2016, we administered a survey with both closed and open-ended questions to 108 adults (locally defined as people aged 16 years or older) from 14 villages in the periphery of RNP. Our overarching goal was to capture ethnobiological knowledge of, and local attitudes towards, bats. Local people living in villages closer to forest are likely to contact more frequently with bat species associated with old-growth forest, whereas in villages further away human-bat interactions are probably more associated with synanthropic bats. As such, village selection was based on convenience sampling, aiming to capture interactions with different species of bats. We therefore sampled both villages closer to the town of Ranomafana and close to



the RNP. To select informants for our interviews, we largely relied on “quota sampling”. Acknowledging that different groups of people tend to have different knowledge and perceptions of bats, we designed our sampling strategy to capture knowledge diversity within each village. Specifically, we created a grid of categories of interest (sex, age, ethnic group) and aimed at having a balanced number of informants per category (see Table 2 for sample composition). To select the people within each of the quotas, we largely relied on the snowballing technique. Although our sampling strategy was designed to capture variability of ethnobiological knowledge, the aim of this paper is not to examine patterns of variability across demographic groups. Our goal was rather to gain a broad overview of the different ways in which people in the area interact with bats, making sure that such overview reflected insights from different sex, age and ethnic groups.

**Table 2** – Summary statistics of survey respondents.

<b>Variable</b>	<b>Category</b>	<b>N</b>	<b>%</b>
Age	<30	28	26
	30-60	59	55
	>60	21	19
Sex	M	54	50
	F	54	50
Ethnic group	Tanala	79	73
	Betsileo	15	14
	Mixed	14	13

The survey included general questions about cultural values around bats, local uses and their representation in folktales (Supplementary material Appendix S1 for full interview protocol). No illustrations or bat specimens were shown to the respondents. As such, we have no way of determining whether folk names are used for a single species or for a wider set of species. The surveys were conducted by three teams of two researchers each. Each team was composed of one foreigner and one Malagasy national, all of whom are co-authors of this manuscript. The survey was first written in English and then translated into Malagasy. The enumerators used the Malagasy version and all quotations in the manuscript represent English translations of responses provided in Malagasy. Data collection adhered to the Code of Ethics of the International Society of

Ethnobiology. Free, Prior and Informed Consent was obtained from all individuals participating in this study, as well as all the relevant political organizations in the area. Research permits were issued by the Ministry of the Environment, Ecology and Forests of Madagascar (Agreement Nr. 275/16/MEEF/SG/DGF/DSAP/SCB.Re) and Madagascar National Parks.

## Results

Most respondents (92%) were aware of the existence of bats in their village or its surroundings and mentioned either one (50%), two (42%) or more (8%) types of bats. The most frequently recognized type of bat was “*kananavy*” (often referred as small, black and mouse-like; named by 80% of the respondents) and “*angavo*” (described as larger than *kananavy*, lighter in colour and sometimes mentioned to eat fruits; named by 30% of the respondents). Other types of bats named included “*fanihy*” (sometimes mentioned as being of intermediate size between *kananavy* and *angavo*, but more often referred to be the same size as *angavo*; named by 13% of the respondents) and “*kepoty*” (considered “small and orange” by one of the respondents but more often referred to be similar to *kananavy*; named by 11% of the respondents, all self-identified as Tanala). According to the descriptions provided, we believe “*kananavy*” and “*kepoty*” to be associated with multiple insectivorous species (e.g., Peters's wrinkle-lipped bat *Mormopterus jugularis*, Madagascar white-bellied free-tailed bat *Mops leucostigma* and Madagascar free-tailed bat *Chaerephon atsinanana*, three highly synanthropic molossids), while “*angavo*” and “*fanihy*” are likely associated with the three species of frugivorous bats found in the island (i.e., Madagascan flying fox *Pteropus rufus*, Madagascan fruit bat *Eidolon dupreanum* and Madagascan rousette *Rousettus madagascariensis*). While over 60% of the respondents of the age group over 60 years old were aware of the existence of *angavo/fanihy*, only ca. 46% of the respondents of the age group 30-60 years old and fewer than 20% of the age group below 30 years old indicated that these megabats inhabited their surroundings.

There appears to be a general understanding of bat ecology, in particular of synanthropic species. A total of 88% of the respondents mentioned that they were aware of where bats sleep or live. Of those, the place most frequently mentioned to be used by bats to sleep or live was people's houses. Twenty seven percent of the interviewees mentioned that bats lived in their own house, and 56% said they knew of bats living in other houses in their village. One informant mentioned that “most houses that have metal roofs have bats” (Fig. 2a). Other interviewees reported that bats lived mostly in the forest (37%), or in caves and the forest (both mentioned by 29% of the interviewees). Over half of the respondents (61%) reported that they knew what bats ate. Of those, 44% mentioned fruits (e.g., guava, litchi, banana, mango and coffee, the latter mentioned by 21% of the responses) and 33% mentioned insects (e.g., beetles, butterflies/moths and mosquitoes, the latter mentioned by 11% of the responses). Two respondents mentioned that bats consumed vertebrates (one mentioned rats and another referred to birds).

**Figure 2** – a) Synanthropic Peters's wrinkle-lipped bat (*Mormopterus jugularis*), known locally as *kananvy* or *kepoty*; b) Malagasy child holding a Peters's wrinkle-lipped bat, in a village close to the edge of RNP; c) Dead Madagascan flying fox *Pteropus rufus*, known locally as *fanihy* or *angavo*, being sold at a local market in the south of Madagascar (Photos: a - Adrià López-Baucells; b and c - Joan de la Malla).



Around one third (32%) of the respondents reported they were aware that other animals preyed on bats. Of these, 23% reported that bats were preyed by birds, mostly nocturnal and diurnal raptors (e.g., owls, hawks and kites) but one respondent also mentioned that bats were consumed by chickens. Additionally, five respondents (14%) mentioned that bats were preyed by dogs, two (6%) by wild carnivores (fossa and mongoose) and one (3%) by cats. For instance, one interviewee mentioned that *“when it rains, the bats come inside [the house], and they fall. Then, the chicken and dogs eat them. When the kids chase them and throw them away, the dog eats them.”*

Out of the 108 respondents, 23 (21%) reported that they had used bat guano as a farm crop fertilizer, 14 (13%) stated that they had consumed bats, four (4%) reported having sold bat meat and two (2%) revealed that they had previously used bats for medicinal purposes. Regarding the latter, respondents mentioned that bats were used for respiratory diseases. “Oil of *kananavy*” was said to be used for curing asthma and one female respondent reported the following: *“My grandmother gave me the *kananavy* to eat. I used it as medicine for the respiratory problems of the kids. We cook it with a lot of water and then we drink the water after. We do not eat the bat for medicine but drink the water. My grandma taught me these things.”* Nine interviewees mentioned that local children captured bats to play with them. One informant reported that *“Sometimes the kids play with bats. They climb to the roofs and catch them. Some of the kids shoot at the bats with their slingshots. The kids play with them. (Fig. 2b)”*. Another one mentioned that *“the kids sometimes try to catch bats when they are flying in the village; kids use sticks to capture the animal. There was a time that some caught and tried to eat *kepoty* after grilling them.”*

Roughly equal numbers of respondents mentioned that bat abundance seemed to have increased as compared to decreased (41 [38%] vs 37 [34%], respectively), relatively to when they were children (ca. 10 years old). Eight respondents (8%) identified contrasting trends in different types of bats. In all but one of these instances, respondents mentioned that *kananavy* were more abundant or had not changed in abundance, whereas both *fanihy* and *angavo* (i.e., fruit bats) had declined, with one respondent stating that they were locally extinct. The most cited reason for the

decline of *fanihy* and *angavo* was hunting (e.g., one interviewee mentioned that “*kananavy is the same [no change in abundance]; fanihy is decreasing. Fanihy is decreasing because some people hunt them. They hunt them a lot. There is a big stone [cave] and people go there to hunt them, both for food and for selling.*” and a second one reported that “*In the houses they are increasing, but in the caves, there are fewer and fewer bats. (...) it is easy to access the caves. There is a real problem. They pay something when they [bats] are captured. There are more people hunting, that's why they are decreasing.*”) but one interviewee mentioned that “*kananavy are just the same. People do not hunt them. Angavo are decreasing. There are fewer, because people kill rats and rats change into bats. So that's why there are fewer bats.*” (Fig. 2c).

Most respondents (61%) described bats as being good and holding positive values (i.e., having a net positive contribution to their lives; 61% vs 26% as neutral and 21% as bad). Of the interviewees that identified bats as good, the most frequent justifications were associated with the “entertainment” value of bats (23%; one respondent stated for instance that “*it is a pleasure to see them flying*”), with the great economic value of their guano (21%), and due to the existential value of bats (14%). Two of the references to the existential value of bats were associated with religious beliefs (e.g., one of the respondents mentioned that “*the Creator made everything to be good and useful*”). However, some of the respondents that considered bats to be good overall, still associated them with negative attributes, such as bad smell. Reasons for describing bats as bad were associated with noise (23%), their physical appearance (23%), their damage to fruits (15%), the damage to buildings associated with their roosting habits (7%) and with the notion that bats are not edible (7%). Most respondents considered bats to be ugly (63% vs 24% beautiful).

Over half of the respondents (55%) identified several benefits associated with bats, most of which related to guano (e.g., one respondent mentioned “*The guano, if there are many [bats]. If there's a small number of bats, then there is no benefit.*”), but also with the consumption of mosquitoes and other insects (e.g., one respondent mentioned that “*they eat insects like mosquitoes and insects that fly.*”) and benefits associated with tourism. For example, one respondent mentioned

that “*They bring tourists. Some tourists came here asking about bats. They were taken to the caves. Three times there have been tourists coming and asking about bats.*”. Only 13 of the 108 respondents (12%) considered bats to be dangerous. Of these, over half associated bats with zoonoses (e.g., one respondent mentioned that “*on the news I heard that bats brought diseases from outside Madagascar, but that they should be protected.*” and another that “*bats may provoke cough and asthma because of the smell*”), two respondents mentioned that they damaged crops, one that they damaged buildings and three other complained about their bad smell, noisy habits and dirtiness associated with guano (e.g., stating “*when I was at school there were many bats on the roof and the guano fell from the roof.*”).

One quarter (25%) of the respondents were aware of *fady* (culturally-enforced taboos) or beliefs related to bats, mostly prohibiting bat hunting and consumption. Several respondents mentioned that bat-related *fady* were due to their physical similarity with rodents (stating e.g., “*it is fady to eat mice or rats. As bats are similar to mice; the ancestors prohibited the consumption of bats*”). Nonetheless, one respondent that was aware of *fady* preventing bat consumption, mentioned that he had previously consumed bats (the last time being ca. three years before the interview), mentioning that “*We never eat the head of the bat, because it looks like a rat. We only eat the body and the wings.*”. On the other hand, only 15% of the respondents mentioned that bats were legally protected, one fifth mentioned the inexistence of any laws associated with bats and one mentioned that “[*hunting is*] *legal outside of the park [RNP], illegal inside*”.

One in four respondents (25%) was aware of folktales related to bats (Table 3). One particularly folktale (with several versions), detailed how bats originated from birds, mentioned fire and had as coprotagonist a popular Malagasy endemic bird, the crested drongo (*Dicrurus forficatus*) (Appendix S2 and S3). Around one third (29%) of the interviewees that knew folktales mentioned the song “*Ity ny apombonao ry kananavy*” (“here is your meal of rice husks, my bat”).

**Table 3** – Examples of bat-related folk narratives mentioned by the interviewees.

<b>Ethnicity</b>	<b>Sex</b>	<b>Age</b>	<b>Folk narratives</b>
Tanala	M	30-60	<i>“There are stories about vampires, many of them. I heard rumours.”</i>
Tanala	M	30-60	<i>“When the guava fruit become yellow, they come to eat them. Then the bat’s meat smells like the fruit.”</i> <i>“Pregnant women do not hear/look/eat the bats, because their baby face will look like a bat.”</i>
Tanala	F	>60	<i>“My parents said that bats are rats and that they got their wings and started to fly. If there are lots of rats in the house, they need to start flying when there is not enough food.”</i>
Tanala	F	30-60	<i>“There is a local myth about bats (kananavy). The Creator had to choose the King of Nature. There were three living creatures that were disappointed by the choice of the Creator. The rice decided to be curved when ready, instead of pointing towards heaven. The bees started to buzz because they were disappointed. And the bats decided to sleep upside down in protest.”</i>
Tanala	M	30-60	<i>“The ancestors told that the rats become bats. They transform. Mice become kananavy. But fanihy turn into rats. The rats in turn become tenrecs after a while.”</i>
Tanala	M	30-60	<i>“They hung upside down, turning their back to the Creator. That's why the Creator made them ugly.”</i>
Betsileo	F	30-60	<i>“Once upon a time, the Creator invited all the birds to a meeting. The bats were late, and the Creator became angry. He said that bats were not part of the Kingdom and then bats got angry against the Creator and turned their backs to him.”</i>
Tanala	F	>60	<i>“When I was a child, I knew that once bats were out it was time to go back to home.”</i>
Tanala	M	30-60	<i>“The bats spread the seeds of trees, but the Creator did not give a compensation. So, now bats show their back to the Creator.”</i>
Tanala	M	<30	<i>“If you catch bat and kill it, the dead bat resuscitates as a mouse.”</i>
Tanala	M	30-60	<i>“The Creator made mice. He decided to separate the ones who lived on the ground and one that could fly. So, he gave wings to bats. At the end bats diverged from mice.”</i>
Tanala	F	<30	<i>“Mice and rats can become bats.”</i>

## Discussion

Understanding human-bat relations in all their complexities is key for designing successful conservation strategies. In this study, we have investigated knowledge of, and attitudes towards bats in the periphery of RNP. Our surveys revealed numerous human-bat interactions and a rich local folklore about bats. However, we suggest that future studies assessing human-bat interactions through an ethnobiological lens in this region should increase representation of different ethnic groups, age classes, and education levels to relate these and other relevant variables to attitudes toward and local ecological knowledge about bats, as conducted in similar studies (e.g., Musila et al. 2018).

### Coexistence Translates into Ethnobiological Knowledge

Knowing that there are at least 14 bat species that inhabit RNP and its surrounding biocultural landscapes (Kemp et al. 2019; López-Baucells et al. 2017; Table 1), it was hardly surprising that most respondents were aware of the existence of bats in their villages and/or in their surroundings. Yet, similar to the findings of Costa Rego et. (2015) in Brazil, only half of the interviewees were able to list more than one type of bat, suggesting that the overall ethnobiological knowledge of local bat diversity is relatively limited. Half of the respondents placed bats into two or more folk taxa. When placing bats into two folk taxa, the categorization largely aligned with the classification of microchiroptera (suborder Microchiroptera) and megachiroptera (family Pteropodidae). This classification of bats in two broad folk taxa is common across several Malayo-Polynesian languages (e.g., Cox 1983; Forth 2021; Tanalgo et al. 2016). However, since we did not use photographs or captured specimens to match local names to Linnean species, we cannot determine whether, among the Tanala and Betsileo ethnic groups, a single lexicalized name might also be used to refer to multiple bat taxa that are identified as morphologically and behaviorally different – as it is the case among Matsigenka Indians of Amazonian Peru (Fleck et al. 2020).

“*Angavo*” and “*fanihy*” seem to be associated in our study area with the three species of frugivorous bats found in Madagascar. However, we note that the Tanala dialect dictionary



(Beaujard 1998) defines *kananavy* as a frugivore, suggesting that elsewhere in Madagascar *kananavy* might also be used to refer to one or multiple Malagasy species of megabats. Fruit bats are conspicuous species (e.g., *P. rufus* has wingspans of over 1 m) with often crepuscular habits that, largely due to intensive hunting, are experiencing steep population declines across much of Madagascar (Cardiff and Jenkins 2016). The indication by seven respondents that *angavo/fanihy* had declined in abundance in relation to when they were young, alongside the observation that the proportion of respondents aware of these bats is considerably smaller in younger age classes (e.g., 60% of the respondents in the age group > 60 years old vs 20% of the age group < 30 years old mentioned *angavo/fanihy*) seems to suggest that the frequency of encounters with frugivorous bats might be decreasing and this might be leading to their erosion from the collective memory of local communities. If so, this might indicate a “shifting baseline syndrome”, something already described in multiple focal ethnobiological systems (e.g., Fernández-Llamazares et al. 2015; Hanazaki et al. 2013; Turvey et al. 2010), but to the best of our knowledge not yet reported in relation to bats.

When it comes to other interspecific interactions with bats, reports of bat predation by three domestic species, namely dogs, cats and chickens are particularly noteworthy. Cats are known bat predators (e.g. Ancillotto et al. 2013; Rocha 2015) and consumption of bats by other domestic species has been previously documented. For instance, Goodman et al. (2008) reported cooked Midas free-tailed bat (*Mops midas*) being fed to domestic pigs in Ambondromamy, northwest Madagascar. Yet, little is known about the interactions between domestic species and bats. Considering its possible implications for both zoonotic disease spillover and bat conservation, this is an area that deserves further ethnobiological investigation.

### **Benefits Associated with Bats**

Guano was reported to be the key benefit associated with bats. Although only one-fifth of the respondents reported having used bat guano, over half of the interviewees that identified bats as beneficial mentioned guano to be the main benefit associated with the group. Likewise, guano-

related income was the most valued benefit associated with bats near Tsimanampetsotsa National Park, in south-western Madagascar (Fernandez-Llamazares et al. 2018). This suggests that under the correct exploration practices, guano harvesting might benefit attitudes towards bats across the island.

Bat meat, particularly of frugivorous species, is widely consumed across Madagascar (Fernandez-Llamazares et al. 2018; Goodman et al. 2008; Jenkins and Racey 2008;) and throughout the Paleotropics (Kamins et al. 2011; Mildenstein et al. 2016; Shapiro et al. 2021; Sheherazade and Tsang 2015;). Although respondents might have underreported bat consumption, only 13% of our informants stated having previously consumed bats. This suggests that bat meat consumption in our study area is not as common as in other Malagasy localities where bats are a food delicacy. This discrepancy is probably due to the rarity of frugivorous bats in RNP. Two respondents mentioned the use of bats for medicinal purposes, providing additional evidence of this practice in Madagascar (see Fernández-Llamazares et al. 2018; Jenkins and Racey 2008), something already reported in Brazil, mainland Africa and multiple Asian countries (Tuladhar-Douglas 2008; da Costa Rego et al. 2015; Mildenstein et al. 2016).

There seems to be an increasing awareness of the ecosystem services provided by bats (Ghanem and Voigt 2012). In accordance, several respondents noted that the consumption of insects by bats, and in particular the consumption of mosquitos, as beneficial. Likewise, Lavery et al. (2021) found that one-fourth of interviewees in a pastoralist community in Namibia considered bats beneficial due to their role in controlling insects. Multiple agricultural pests and disease vectors have been identified in the diet of insectivorous bats in our study area (Kemp et al. 2019). However, none of the respondents specifically mentioned the potential existence of agricultural benefits associated with top-down suppression of damaging arthropods. Yet, one folktale shared by a respondent mentioned that bats show their backs to the creator as an act of rebellion due to the absence of compensation for their role as seed dispersers, revealing some understanding of the ecosystem services provided by bats.

## **Human-Bat Conflicts**

Most of the respondents that identified bats as bad complained about noise and damage to buildings associated with synanthropic species, reinforcing the need for evidence-based guidance for the management of synanthropic bat colonies in rural Madagascar. Such negative feelings towards bats as a result of noise, bad smell, and guano are not uncommon in other places where humans and bats cohabitate (Voight et al. 2016; Shapiro et al. 2021). In our study area, six species were found to roost in buildings, most in small groups of up to tens of individuals, but in certain circumstances in large colonies of several hundred individuals (López-Baucells et al. 2017). As indicated by one of the respondents, synanthropic bats in the area tend to roost under sheet metal roofs, within large empty cavities (López-Baucells et al. 2017), a building type that is becoming increasingly frequent in our study area.

Several zoonotic pathogens have been associated with bats, and direct and indirect zoonotic spillover from bats to humans is a non-negligible risk and source of conflict (Schneeberger and Voigt 2016). Over half of the respondents that identified bats as dangerous indicated zoonotic risks as the main reason for their dislike of the species. Previous studies (e.g., da Costa Rego et al. 2015; Laverty et al. 2021; Sasse and Gramza 2000; Shapiro et al. 2020; Shapiro et al. 2021) had already identified perceived zoonotic risks as key reasons for their bad reputation. Research into bat-associated zoonoses is of critical importance and a clear priority (Rocha et al. 2020). Yet, informing the public about the potential health risks associated with bats, without eroding the already limited support for their conservation, is a complex task that requires transdisciplinary collaboration and evidence-based messaging (López-Baucells et al. 2018). The failure to properly communicate disease risks can jeopardize the long-term persistence of this diverse group and the multiple ecosystem services it provides (MacFarlane and Rocha 2020).

## **Taboos and Folklore Associated with Bats**

Malagasy culture is rich in cultural taboos and ancestral customs (Golden and Comaroff 2015; Jones et al. 2008; Lingard et al. 2003; Tengö et al. 2007). Although around a quarter of the respondents mentioned the existence of bat-associated *fady*, none identified any bat-specific ones. Instead, multiple respondents mentioned that the prohibition on consuming bats derived from their similarity with rodents and with the fact that eating mice and rats is considered taboo. This, in combination with multiple references to the belief that “*mice and rats can become bats*” suggests that rodent-associated taboos might be responsible for some of the taboos associated with bats in our study area. Contrary to findings in south-western Madagascar (Fernandez-Llamazares et al. 2018), our surveys in RNP did not reveal any cave-associated taboos that might benefit bat conservation.

Bats are commonly featured in folklore (Kingston 2016; Eklöf and Rydell 2021; Forth 2021; Low et al. 2021) and our results show that Madagascar is no exception to this global pattern. Some myths, such as the belief that bats are rodents that developed wings or that pregnant women should not consume bats because otherwise their babies will be ugly, are not exclusive to Madagascar. Similar accounts regarding bats being rodents with wings are known from Brazil (Silva et al. 2013) and in multiple languages the word “bat” is associated with rats/mice e.g., *fledermaus* (German), which translates for flying mouse or *morcego* (Portuguese), which translates for blind mouse. Likewise, the same belief about pregnant women is also present in Ghana (Ohemeng et al. 2017). Other stories, however, such as the popular tale about the interaction between a bat, a crested drongo and the creator, are more context-specific (the crested drongo is endemic to Madagascar). Other Malagasy folktales about bats include a myth about the origin of Madagascan flying fox (Beaujard 1991), but additional ones might exist. The rich local folklore about bats has a great potential to bridge the biological and cultural conservation agendas and inspire biocultural approaches to conservation (Fernández-Llamazares and Cabeza 2018).

Although one of the respondents mentioned stories of vampirism, none of the interviewees seemed to associate bats with death. This suggests that at least some of the most popular myths and

folklore associated with bats in the Western culture (e.g., Prokop et al. 2009) are not common in our study area. This probably reflects limited local exposure to Western communication channels.

## **Conclusions**

This study provides an initial account of the intricate human-bat interactions in rural Madagascar and opens the door to further our understanding of the ethnobiological importance of bats. We found that a close coexistence between humans and bats translated into a considerable body of ethnobiological knowledge of bats and some of the benefits they provide to human well-being. While most respondents considered bats not to be dangerous, some mentioned that bats could carry diseases and complained about the bad smell and noise associated with bat roosts in people's houses and public buildings. Accordingly, our results indicate that stigmatization due to perceived zoonotic risks and negative feelings towards synanthropic bats might lead to the erosion of the cultural values that the Malagasy society has traditionally placed on these flying mammals.

Understanding the human dimensions of bat conservation is of particular importance on tropical islands such as Madagascar, on which endemic and globally threatened species are particularly common (Conenna et al. 2017). We believe that the richness of cultural representations of bats in local folklore, and the many different positive values attributed to bats, have great potential to guide and inform biocultural approaches to conservation in Madagascar and elsewhere. Conservation campaigns often fail to rely on culturally-grounded and local perspectives and therefore risk lacking social legitimacy. Assessments of local ecological knowledge and cultural values can be used to design ethically acceptable and culturally-appropriate social marketing conservation campaigns, ensuring that conservation information is tailored to the local biocultural context (Fernández-Llamazares and Cabeza 2018).

## Acknowledgements

We thank the Tanala and Betsileo people who have so generously opened for us the doors of their ethnobiological worlds, Madagascar National Parks for their support, Association SAME for help during fieldwork and translation services, and A. Pyhälä and V. Reyes-García for insightful comments about our interview protocol. We also thank Centre Valbio staff for their hospitality and logistical support, the Ministry of the Environment, Ecology and Forests of Madagascar for providing the research permit, and Steve Goodman for information about the bats of Ranomafana. This work benefited from funding from the Academy of Finland (grants 311176 and 292765), the Portuguese Foundation for Science and Technology (grants PD/BD/52597/2014 and SFRH/BD/80488/2011) and ARDITI – Madeira’s Regional Agency for the Development of Research, Technology and Innovation (grant M1420-09-5369-FSE-000002).

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# **Appendices**

## **Human-bat interactions in rural southwestern Madagascar from a biocultural lens**

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### **This supplementary material contains:**

**Appendix S1.** Questionnaire on bat-human interactions.

**Appendix S2.** Malagasy folktale about bats, the crested drongo and fire.

**Appendix S3.** Photo of Malagasy crested drongo.

## Appendix S1. Questionnaire on Bat-Human Interactions

### General information

1. Interviewer: \_\_\_\_\_
2. Translator: \_\_\_\_\_
3. Village name: \_\_\_\_\_
4. Date: \_\_\_\_\_
5. Sex: \_\_\_\_\_
6. Ethnic group: \_\_\_\_\_
7. Estimated age: <30 / 30-60 / >60
8. Schooling: yes / no
9. Conservation-related job: yes / no  
Which one? \_\_\_\_\_

### Bat presence in the village

10. Are there bats in this village (and its surroundings)? yes / no
  
11. Where do they live/sleep?  
In my house \_\_\_\_\_  
In other houses \_\_\_\_\_  
In the school \_\_\_\_\_  
In the trees \_\_\_\_\_  
In caves \_\_\_\_\_  
In mines \_\_\_\_\_  
Other \_\_\_\_\_  
Don't know \_\_\_\_\_

### Local uses of bats

12. Do you use the bats in any way?  
For food (subsistence) \_\_\_\_\_  
For food (selling) \_\_\_\_\_  
To whom do you sell? \_\_\_\_\_  
For how many *ariary*? \_\_\_\_\_  
For medicinal purposes \_\_\_\_\_  
For the guano \_\_\_\_\_  
Kids play with them \_\_\_\_\_  
Others \_\_\_\_\_
  
13. Do the people of your community use the bats in any way?  
For food (subsistence) \_\_\_\_\_  
For food (selling) \_\_\_\_\_  
To whom do they sell \_\_\_\_\_  
For how many *ariary*? \_\_\_\_\_  
For medicinal purposes \_\_\_\_\_  
For the guano \_\_\_\_\_  
Kids play with them \_\_\_\_\_  
Others \_\_\_\_\_

**Perceptions of bats**

14. Compared to when you were a kid (ca. 10 years old), do you think that bats are nowadays

- More abundant
- Same as before
- Less abundant
- Don't know

15. Why do you think that bats are more/less/same abundant than before (i.e., your childhood)?

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16. In general, do you think bats are good or bad, or neither good nor bad?

- |                      |             |       |
|----------------------|-------------|-------|
| Good                 | If so, why? | _____ |
| Bad                  | If so, why? | _____ |
| Neither good nor bad | If so, why? | _____ |

17. In general, do you think bats are beautiful or ugly, or neither beautiful nor ugly?

- Beautiful
- Ugly
- Neither beautiful nor ugly

18. Do you think there are any dangers related to bats? yes / no

If yes, in what way(s)?

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19. Do you think there are any benefits related to bats? yes / no

If yes, in what way(s)?

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**Bat and cave conservation**

20. Are there any *fady* (taboos) or beliefs related to bats and/or caves?

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21. Are there any stories, myths, legends, or folktales related to bats and/or caves?

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22. Do you know if bats are protected? yes / no

If yes, where?

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**Local knowledge of bats**

23. Are there just one kind/type of bat or more than one kind/type of bat in this area?

One kind/type



Several kinds/types  
Don't know

24. If more than one kind/type, do you have local names? yes / no  
If yes, please list all the different kinds/types of bats you know in the area and how you differentiate them?

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25. Do you know what bats eat? yes / no  
If yes, what?

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26. Do you know how bats interact with other animals in the forest? yes / no  
If yes, how?

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27. Anything else you know or want to tell us about bats?

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*MISAOTRA BETSAKA!*

**Appendix S2.** Three versions of the Malagasy folktale about bats, the crested drongo and fire.

*“Once upon a time, the Creator gave rise to bats as well as all other birds in the world. Bats and other birds were allocated to one place by the Creator. Every day, some birds went out to look for food and some stayed to guard the place. One day, a large fire started and all the birds rushed to fight it. It was eventually controlled and then the Creator asked: “who put down the fire?” All birds came to the Creator and the bat (fanihy) replied that he had been the one to put down the fire but, as his clothes were too clean, the Creator was aware that he was lying. The Creator realised that the drongo (railovy) had been the one to put down the fire and during the process his clothes, which were originally white, changed to black due to the ash from the fire. This shift in the color of the drongo (white to black) proved that he fought the fire. Accordingly, the Creator gave the drongo the glory of becoming the king of all birds by crowning him with a crest on top of his head. The bat got angry with the decision of the Creator and turned his bottom up, in the direction of the Creator. As a response, the Creator punished all bats by saying: “you will stay like this in the rest of your life and you will grow teeth”. That is why bats hang in reverse position and have teeth. ” (Male, Betsileo, 30-60 age group)*

*“The Creator called all birds. When they arrived, he started a large fire and said: “The one that puts down the fire will be the crowned king”. All the birds tried to stop the fire but only bats (angavo), with their large wings, were successful. In the process they burned their feathers and their skin turned wrinkled. Nonetheless, the Creator called all the birds and proclaimed the drongo (railovy) the king of the birds, because the drongo had been very fast in reaching the Creator and telling him that he had stopped the fire. In the eyes of the Creator, the drongo was the king of the birds. Angavo had burned his wings, so he could not fly fast enough. The drongo, with his intact wings, was faster. As a consequence, the drongo became the king of the birds for the Malagasy people. Angavo was angry and disappointed with the Creator because he had been the one that actually stopped the fire. Since that day, all bats decided to turn their back to the Creator as he had ignored their actions.” (Female, Betsileo, 30-60 age group)*

*“There was a big fire. The Creator said that the bird which is able to put out the fire would become the king of all birds. The bat (Angavo) managed to put down the fire but before going to see the Creator, he went to the river to wash himself so as to look presentable to the Creator. The drongo (railovy) did not wash the dirt off and as such arrived first to the Creator. The drongo looked black and dirty and the bat was clean, so the Creator thought that the drongo had been the one to fight fire and crowned him king. The bat was disappointed as a response turned his back to the Creator.” (Male, Mixed, >60 age group)*

**Appendix S3.** Malagasy crested drongo (*Dicrurus forficatus*). Photo by Ricardo Rocha.

