The stories people tell, and how they can contribute to our understanding of megafaunal decline and extinction in Madagascar

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Abstract

Most researchers believe that Madagascar's megafauna went extinct between 2000 and 1000 years ago. Across Madagascar, fossil specimens of the island's endemic (and now extinct) pygmy hippopotamuses, elephant birds, giant lemurs, horned crocodiles, and other vertebrates larger in body size than 10 kg commonly date to the first millennium of the Common Era (CE) or earlier; few records date to the second millennium CE. Whereas megafaunal populations appear to have crashed almost simultaneously near the end of the first millennium CE, small populations can survive in remote pockets for centuries after precipitous species decline, perhaps longer. Examining the differences in the population dynamics of declining species and other factors can help to better identify the ultimate timing of extinction.

Ever since Etienne de Flacourt traveled to Madagascar in the late 1600s, Malagasy stories of large-bodied wild animals have been recorded. Many include fantastic, clearly mythical creatures, but some provide anatomical or behavioral details which are consistent with legends or even direct observations of real, albeit potentially already extinct, species (including elephant birds, hippopotamuses, and some giant lemurs).

In December 1989, at 06:00 hours, one of us (BZF) witnessed a large euplerid carnivoran locally known as *fosabe* (big fosa) or *fosa jobijoby* (blackish fosa) who had entered his field tent at Montagne d'Ambre. The animal was "twice the size and much darker than the common fossa" (Freed, 1996, p. 34). The individual was black and weighed approximately 20-25 kg. Freed wrote that the animal was well known to the local people and that "many local people also reported seeing it". The animal fits paleontologists' expectations for *Cryptoprocta spelea*, a large carnivoran known from the fossil record, believed to have been extinct for at least 1000 years.

In June 2020, we recorded modern accounts of the big fosa. One of us (ESN) visited villages in four different sectors (Northwest, Northeast, East, and West) of Montagne d'Ambre National Park and the Forêt d'Ambre Special Reserve to examine potential regional differences and/or similarities in the stories of this animal, and whether such accounts include mythical elements, relevant anatomical information, and/or credible recent sightings. We also recorded stories of an Endangered extant animal, the aye-aye of the genus *Daubentonia* (also known locally as the *kakahely*). Ultimately, we believe this folklore provides clues that may help elucidate the geography of decline and possible late survival of an "extinct" megafaunal animal on Madagascar.

Key words: Montagne d'Ambre, *Cryptoprocta spelea*, *fosa be*, *Daubentonia madagascariensis*, *kakahely*, extinction, collective oral memory

Résumé détaillé

La plupart des chercheurs pensent que la mégafaune de Madagascar a disparu il y a 1000 à 2000 ans. A travers Madagascar, les hippopotames nains endémiques (maintenant éteints) de l'île, les oiseaux-éléphants, les lémuriens géants, les crocodiles à cornes et d'autres vertébrés de plus de 10 kg datent généralement du premier millénaire de l'ère commune (EC) ou avant. Il existe peu de documents datant du deuxième millénaire de notre ère. Alors que les populations mégafaunes semblent s'être éteintes presque simultanément vers la fin du premier millénaire de notre ère, les différences sur la dynamique des populations des espèces en déclin

Nomenjanahary, E. S., Freed, B. Z., Dollar, L. J., Randrianasy, J. & Godfrey, L. R. 2021. The stories people tell, and how they can contribute to our understanding of megafaunal decline and extinction in Madagascar, eds. K. Douglass, L. R. Godfrey & D. A. Burney. *Malagasy Nature*, 15: 159-179.

et d'autres facteurs peuvent entraîner une variation dans leur période d'extinction. Les petites populations peuvent survivre dans des poches isolées pendant des siècles après le déclin précipité des espèces, peut-être plus longtemps.

Depuis qu'Etienne de Flacourt s'est rendu à Madagascar à la fin des années 1600, des histoires malgaches sur des espèces sauvages de grandes tailles ou des monstres ont été enregistrées. Beaucoup incluent des créatures fantastiques, clairement mythiques, mais certaines fournissent des détails anatomiques ou comportementaux cohérents avec l'idée qu'ils sont basés sur des légendes ou même des observations directes d'espèces réelles (y compris les oiseaux-éléphants, les hippopotames et certains lémuriens géants). Ces animaux peuvent avoir déjà été éteints lorsque les contes ont été relatés.

En décembre 1989, l'un d'entre nous (BZF) a vu à la Montagne d'Ambre un grand carnivore connu localement sous le nom de *fosabe* (grande fosa) ou *fosa jobijoby* (fosa noirâtre) griffant sa tente dans le campement aux alentours de 6 heures du matin. Il a décrit l'animal comme « deux fois plus grand et beaucoup plus sombre que le *fosa* commun » (Freed, 1996, p. 34). L'individu était noir et pesait environ 20-25 kg. Freed a écrit que l'animal était bien connu de la population locale et que « de nombreux habitants de la région ont également déclaré l'avoir vu ». L'animal correspond aux attentes des paléontologues pour *Cryptoprocta spelea*, un grand fosa fossile que l'on croit éteinte depuis au moins 1000 ans.

En juin 2020, nous avons recherché des récits modernes du grand fosa. L'un d'entre nous (ESN) a visité des villages à proximité de quatre secteurs (Nord-ouest, Nord-est, Est et Ouest) du Parc National de la Montagne d'Ambre et de la Réserve Spéciale de la Forêt d'Ambre. Notre objectif était de voir s'il y a des différences régionales ou des éléments communs sur les histoires de cet animal. Plus précisément, ces récits incluent-ils des éléments mythiques, des informations anatomiques pertinentes et / ou des observations récentes crédibles ? Nous avons également enregistré des histoires d'un animal existant en voie de disparition, l'aye-aye du genre *Daubentonia* (également connu localement sous le nom de *kakahely*). En fin de compte, nous pensons que ce folklore fournit des indices qui peuvent aider à élucider la possibilité de la survie tardive d'un animal reconnu comme « éteint » sur l'île de Madagascar.

Mots clés : Montagne d'Ambre, *Cryptoprocta spelea*, *fosa be*, *Daubentonia madagascariensis*, *kakahely*, extinction, mémoire oral collectif

Introduction

In the past century, small populations of a number of vertebrate species, long thought to be extinct, have been found (Fisher, 2011; Fisher & Blomberg, 2011; Lee *et al*., 2017). The list includes relatively large mammals such as the Chacoan peccary, *Catagonus wagneri* (Wetzel *et al*., 1975), and the Nepalese wild yak, *Bos mutus* (Acharya *et al*., 2016), as well as showy flightless birds such as *Porphyrio hochstetteri* (Grueber & Jamieson, 2011). Almost invariably, the existence of these animals is no surprise to the people native to the region where the animal was 'discovered,' often by foreign scientists. Madagascar is no exception to the phenomenon. At a national meeting of the American Association of Physical Anthropologists, a well-known paleontologist commented on the probable extinction of the greater bamboo lemur, *Hapalemur simus* (now called *Prolemur simus*). Shortly thereafter, its 'rediscovery' (Meier & Rumpler, 1987) was hailed in Western media as remarkable, but its existence was never lost to the Malagasy people, nor to the Western scientists working with them (Wilson, 1987). Working with local communities, Ravaloharimanitra *et al*. (2011) surveyed 44 sites in the eastern portion of the island and along or near the Ankeniheny-Zahamena Corridor, found evidence of *Prolemur simus* at 18 sites, and directly observed the species at six.

Local people have also been vitally important in helping scientists find the remains of extinct animals, including species whose existence they may remember. French explorer Alfred Grandidier is credited with having 'discovered' the subfossil site Ambolisatra (southwest Madagascar) in the mid-1800s. In reality, Grandidier did not discover the site. Instead, a village headman led Grandidier to the site after he asked about the legendary beast called the *songomby* (Grandidier, 1871). The village headman recognized this as the pygmy hippopotamus and brought the foreigner to a pond where lots of bones of the pygmy hippopotamus, alongside those of elephant birds and giant lemurs, could be found. It was the collective knowledge of local people that led Alfred Grandidier to this site. It was this knowledge of local people in the regions of Ampasambazimba (central Madagascar) in the early 1900s and Belo-sur-Mer (on the west coast) in the late 1900s which

also led Godfrey (1986) and Burney & Ramilisonina (1998) to speculate that Madagascar's unique pygmy hippopotamuses may have survived in pockets not merely into the late-1800s, but well into the 20th century.

Cryptoprocta spelea, the "cave fosa", is a member of the family Eupleridae endemic to Madagascar and is named for the fact that many of its bones have been found in caves. It is the largest known Holocene mammalian carnivoran in Madagascar, and it is known to science only from its remains found in subfossil sites across the island. This species is widely believed to have become extinct between 2000 and 1000 years ago. Three radiocarbon dates have been published for *C. spelea* from subfossil sites (Crowley, 2010). The most recent is for a specimen from Grotte d'Ankazoabo in the coastal region of the southwest (CAMS 143077; calibrated date 1767.5 ± 67.5 cal BP). The two additional dates come from a southwestern inland site, Taolambiby, and span the period from slightly over 3000 to slightly under 2000 years ago (CAMS 143062, 3290 ± 85 cal BP; CAMS 142717, 1933 ± 68 cal BP). While not one date is from the last millennium, radiocarbon dates for this species are too few to accord any confidence to estimates of the timing of its apparent extinction.

Subfossil remains of *Cryptoprocta spelea* are known primarily from southern (Andrahomana and Beloha Anavoha), southwestern (Grotte d'Ankazoabo, Beavoha, Bemafandry, Lelia, Taolambiby, Tsiandroina, and Tsimanampesotse), south central (Christmas River), and western (Belo-sur-Mer) Madagascar (Goodman *et al*., 2004; Meador *et al*., 2019; Lewis *et al*., unpublished data). Additionally, their presence in cave deposits of the northwest (Beanka Reserve, see Burney *et al*., 2020) has been reported, as has their presence in the extreme north at the Ankarana Massif and Lakaton'ny Akanga at the Montagne des Français and both sites within 80 km of Montagne d'Ambre (Goodman *et al*., 2004). However, subfossil remains of *C. spelea* are far less common in the extreme north than are remains of *C. ferox*, raising the possibility that *C. spelea* has been gone from the area for an extended period of time.

The research described in this article was inspired by an incident that occurred in 1989. At that time, one of the authors (BZF) was conducting field research for his doctoral degree in anthropology (Freed, 1996) at Ampamelonabe, in the western part of Montagne d'Ambre National Park. In his own words (based largely on original field notes):

"In December 1989, at Ampamelonabe main camp, I awoke at about 0600h to a strange noise coming from the supply tent that was 6 meters away. All tents were on wooden platforms. I descended slowly from my tent to see a long black tail extending from the supply tent, while a clanging and pushing sound came from inside the tent. The animal had partially destroyed it. As I took a step closer to the tent, the animal turned around, first bumping its head against the tent fly, and then it repositioned itself with its head looking directly at me, staring out from the tent entrance."

"It looked like a fosa. But this was no reddish-brown *Cryptoprocta ferox*; I had seen plenty of those in daylight at the site. Its head was solid black, as were its body and tail. Its head, body, and tail were much larger than those of *C. ferox*. The head was big, and the animal didn't have the rounded ears that characterize *C. ferox*. I estimated its body mass at maybe 20-25 kg. Only a few seconds later, it ran off very fast away from me."

"My initial reaction was disbelief. After a few seconds, I tried to follow the animal, but it was already long gone. What had I seen? The size and color just were so different from *C. ferox*. It was SO big, and it was very black. No *C. ferox* ever looked like that."

"Its head and body (without the tail) must have been over one meter in length. The tent's floor length was 152 cm, and given its position in the tent when it bumped its head against the fly, I could estimate its length from the tip of its nose to the base of tail at between 102-115 cm. Plus, it had a very long tail, just as does *C. ferox* (almost as long as its head and body)."

"At that time, in 1989, I knew nothing about *Cryptoprocta spelea*, a relative of *C. ferox* believed to be long extinct. I was perplexed by what I had seen. I packed up my backpack and headed to Joffreville. On the way, I was convinced that I had seen one of two things. My first explanation was that I had seen a black panther. But a large felid of this sort had never been reported on the island! As I started doubting that possibility, and while attempting to describe it to the forestry agents at the park barrier, I remembered my guide's description of TWO different kinds of fosa in the forest. I asked him about their coat colors. One was reddish-brown, he said, and it preyed on lemurs or crested ibis. This was clearly *C. ferox*. The other one was much larger, black, and it could take down cattle. To confirm, I asked him if this second one was 'noir.' Yes, he stated, but he also said that

he had never personally seen it. So I was inclined to dismiss the idea that there were indeed two species of *Cryptoprocta* in the forest, and embrace the notion that someone had introduced a large black felid to Madagascar."

"After that morning, however, I realized that the second was the better of my two explanations. What I had seen matched my guide's description of the larger fosa. I could not imagine this black fosa preying on lemurs; it was so much longer, bigger, and stronger than *C. ferox*. I didn't think about the fact that, in the late Holocene, there were also much bigger lemurs living in the forest. I also did not recall that large predators that lose their habitual prey will turn to smaller prey species to survive."

"When later I visited the World Wildlife Fund technical consultant in Diego, he asked why I hadn't photographed the animal. Honestly, the camera was in the supply tent which the fosa had severely damaged."

"When in 1992 I told my dissertation advisor about this incident, he suggested that maybe it was a melanistic form of something. But it was so much bigger than *C. ferox*. I had previously been within 0.5 meters of a *C. ferox* on a couple of occasions, so I knew its size."

"In 2004, after Goodman *et al.* (2004) published their article on the specific identification of subfossil *Cryptoprocta*, one of my fellow former graduate students sent me a copy of that article and suggested that maybe *C. spelea* was what I had seen. But most of my colleagues remained skeptical. After all, everybody knew that *Cryptoprocta spelea* was long extinct."

In this article, we explore modern descriptions of the large carnivoran in the far north of Madagascar, as told in Malagasy by local residents living on and around Montagne d'Ambre. Such stories are common in this region. We consider the possibility that the large carnivoran featured in these stories is *C. spelea*, and that it has either very recently become extinct, or is still extant.

Methods

Site description

We define Montagne d'Ambre as the approximately 23,000 ha region (estimated in 1989) which includes both the Montagne d'Ambre National Park and the Forêt d'Ambre Special Reserve. Most of Montagne d'Ambre is volcanic in origin and contains continuous moist evergreen forest, but peripheral areas vary in ecological structure, geology, and degree of conservation threat. Our initial observations in Montagne d'Ambre include those from 1989, with a three-year long behavioral study of lemurs, and multidisciplinary surveys of the region in 2004-2017 (see Freed, 1996, 2012; Gezon *et al.*, 2005; Goodman *et al*., 2018).

Montagne d'Ambre is divided into several regions, based on geography, climate, accessibility, and disturbance (Freed, 1996; see Figure 1). Whereas the Northeast, East, Interior, and South contain moist evergreen forest, the West and Northwest receive much less precipitation, and forests there are much drier. In terms of accessibility, permanent roads exist only up to the eastern and northeastern range of the forest. In the West, once passable secondary roads, constructed to facilitate logging, have long since fallen into disrepair. Footpaths lead most villages to the forest, and two major paths traverse the forest. People readily use these two paths, as they are vital for maintaining economic and social ties. Residence within the forest is rare, except for the few households near the tourist region of Station des Roussettes in the interior.

Although the kinds of forest disturbance have not changed much since 1989, the extent of disturbance has increased. Logging and deforestation have occurred extensively in the Northwest and Northeast. Whereas intensive agriculture and extensive farming exist along the Northeast, East, and South, rice agriculture, small family farms, and maize production exist in the West and Northwest (Freed, 2012). In the Northeast, extensive pineapple plantations occurred in the 1980s through 1990s, but these are no longer operational. Extensive mango groves also occurred in this region, but these have also decreased extensively. Fruit and *khat* (*Catha edulis*) are grown throughout much of the East and South.

Except for the Interior, each region is within 10 km of between three and five towns of 200-5,000 inhabitants each. Overall, the connection that people have to Montagne d'Ambre varies historically and ethnically. Although most people native to the region are ethnically Antakarana or Sakalava, since 1984 many other ethnic groups with different traditions, including Tsimihety, Betsileo, and Betsimisaraka, have moved into the area to facilitate logging and agriculture, especially in the Northwest, Northeast, and East. Given this variation, we expected some regional differences in local people's knowledge and accumulated history of the forest and its wildlife.

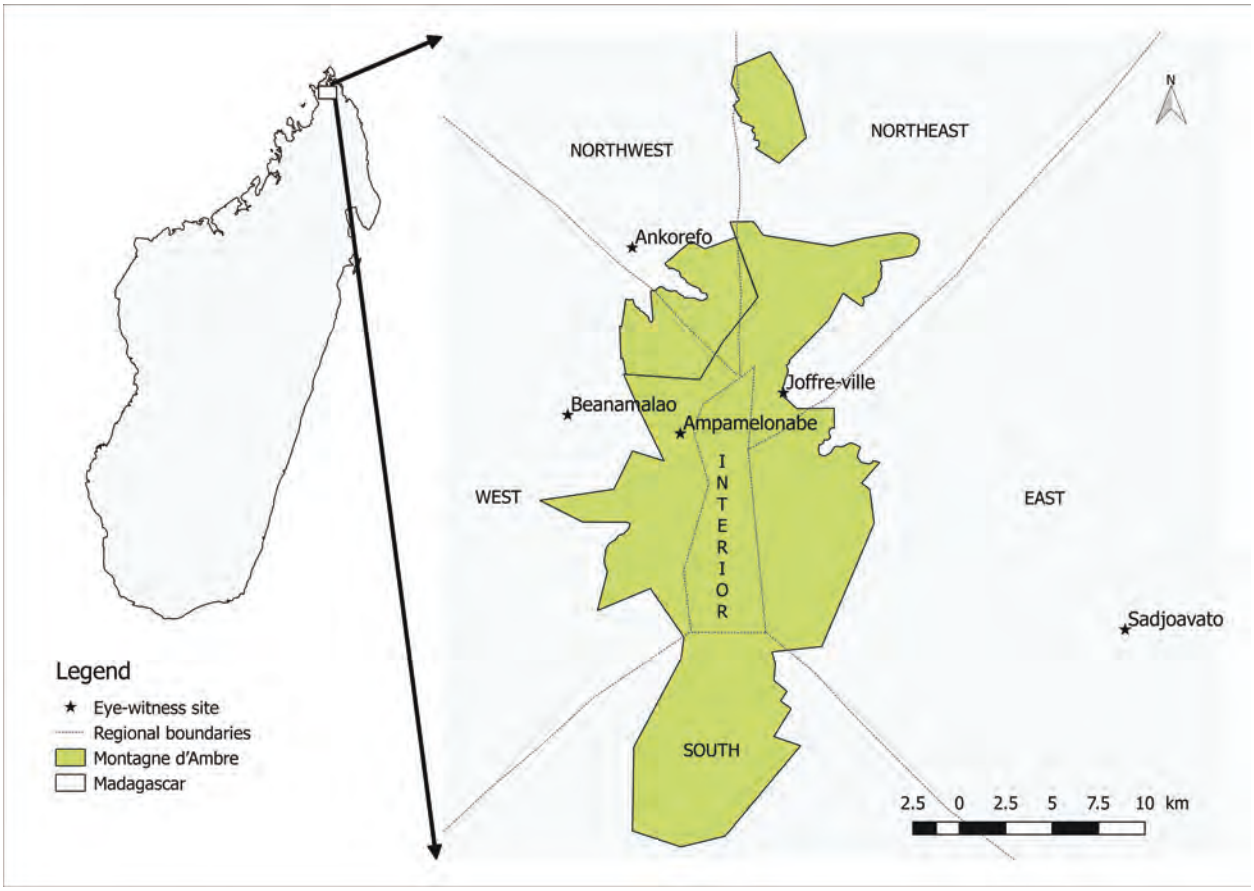

Figure 1. Map of Montagne d'Ambre showing study regions and the locations of apparent eyewitness accounts of *Cryptoprocta spelea*.

Whereas Joffreville in the Northeast has had a long, extensive connection to Antsiranana, the regional capital, most people in other regions surrounding the massif have limited access to this large city.

Interviews

We report here the results of interviews conducted in June 2020 by the lead author (ESN) and local guide Louis Philippe d'Arvisenet in the local dialect of Malagasy. The pair conducted a total of 90 Interviews (21 in the Northwest, 23 in the Northeast, 25 in the West, and 21 in the East). For each region, interviews took place in two *fokontany* or commune, each represented by a single village with multiple hamlets (or clusters of houses). All villages were located outside the perimeter of the park.

When entering each *fokontany*, before conducting interviews, ESN and her local guide spoke with the president of the *fokontany* and/or that person's assistant to obtain official permission to conduct the interviews. They explained who ESN is, where she is from, and why she was interested in speaking with people in the villages. They also requested names of older people who might have longer-term knowledge of the animals in the area. In each village, they particularly sought to interview older individuals, students, and forest agents. All interviews were recorded with permission of the interviewee. Each was later transcribed in full, and then translated first into official Malagasy and French, and then portions relevant to this project were translated into English. All interviews occurred in a relaxed environment (usually in the home of the interviewee but sometimes in a rice paddy or other types of agricultural fields). Information regarding the age and sex of the interviewee was recorded at the start of each interview, and interviews began with ESN explaining who she is and that she was interested in finding out something about the carnivorans living in the region. ESN asked each interviewee to describe his or her knowledge of, and experience with the *fosa*, including stories they had heard, and those told to children by the elderly. Interviews were unstructured and open-response to help prevent interviewer questions from influencing results. Care was taken to avoid asking leading questions, questions specifically addressing more than one type of *fosa*, or questions about a big or dangerous *fosa*. Interviewees were informed that their identities would be protected. When the

interviewee volunteered information regarding other animals (non-carnivorans), they were encouraged to elaborate. In this manner, aye-ayes became a secondary focus of this study.

Data analysis

Our first task was to identify all carnivoran and other species described by interviewees, and their local names. We brought to our interpretations of their scientific identity our prior knowledge of local endemic and introduced carnivorans and their characteristics, derived in part from prior wildlife surveys and from published data as well as measurements that we had taken on euplerid and canid specimens in museum collections. To determine whether the largest described carnivoran might actually be a species believed by Western scientists to be extinct, we also compared measurements of the long bones of *Cryptoprocta spelea*, to those of its congener, *C. ferox*, and to those of *Canis familiaris* in the collections of the Université d'Antananarivo and published records from within and outside of Madagascar (Harcourt, 1974; Goodman *et al*., 2004; Onar & Belli, 2005; Detry & Cardosa, 2010; Goodman, 2012).

For our statistical analysis of interview data, interviewees were identified by region (West, Northwest, Northeast, East), sex (male, female), and age (<50 years or ≥50 years). To protect the respondents' identities, we omitted their names and villages from the database. We then coded only the portions of interview data pertaining to large carnivorans. We constructed a total of 19 themes, designed to best capture the essence of the interviews. For each respondent, we scored themes as 1 if the respondent provided affirmative information, and 0 if the respondent either claimed the opposite or did not address the question at all. Thus, we used 1 = "yes" and 0 = "no" for the following 19 themes, and we scored each when and only when a large carnivoran was described by the interviewee:

T1 The interviewee claims to have personally seen the animal.
T2 The interviewee compares the size of the animal to that of a large dog.
T3 The interviewee claims that the animal has an elongated chest or trunk.
T4 The interviewee contrasted the relative lengths of the fore- and hind limbs, claiming that the animal has much shorter forelimbs.
T5 The interviewee claims that the animal climbs trees.
T6 The interviewee claims that the animal is found often (or entirely) in the forest.
T7 The interviewee claims that the animal is dangerous.
T8 The interviewee claims to be personally afraid of the animal.
T9 The interviewee describes the animal as having black pelage.
T10 The interviewee describes the animal as having red (reddish or ginger) pelage.
T11 The interviewee describes the animal as having gray or ash pelage.
T12 The interviewee describes the animal as having mixed or mottled coloration.
T13 The interviewee says that the muzzle is black.
T14 The interviewee says the animal is more aggressive during the breeding season.
T15 The interviewee claims that the animal can kill a dog.
T16 The interviewee claims the animal can kill a cow, pig, or wild bush pig (perhaps specifying young or sick individuals).
T17 The interviewee claims the animal can kill a person.
T18 The interviewee claims that the animal feeds on lemurs.
T19 The interviewee claims the animal raids chicken coops.

For our data analysis, we used Excel, SPSS, Minitab, and the R-environment. In addition to compiling descriptive data on the large carnivoran, we evaluated differences in the descriptions of young and older interviewees (individuals younger and older than 50), male and female interviewees, and interviewees from different regions surrounding Montagne d'Ambre. Statistical tools used to evaluate regional differences and similarities included correlation analysis (with significance level set at 0.05), multiple discriminant function analysis and Euclidean distance analysis.

Results

Inferring species

Collectively, the 90 interviewees described all four of the known euplerids on Montagne d'Ambre: *Galidia elegans*, *Fossa fossana*, *Eupleres goudotii*, and *Cryptoprocta ferox.* On occasion, interviewees knew the scientific name of the animal being described and would give both local and scientific names. In the great majority of cases, we were able to deduce the scientific identity of extant animals from their descriptions (pelage, size, physical attributes,

and behavior) and via comparisons to additional animals (e.g., animal A is bigger than animal B but smaller than animal C). In addition to describing each of the known extant euplerids in the forest, some interviewees described a fifth euplerid species, i.e., a very large fosa, matching in many details the animal that BZF had encountered and discussed in the introduction. The term *fosa* was used to describe each of these euplerid species with different modifiers (e.g., *fosa fitry*, *fosa varika*, *fosa vato*, *fosa fangoko*, *fosa be*, *fosa maventy*, *fosa jobijoby*; Table 1). Finally, respondents also sometimes described other animals which they considered dangerous, including a lemur, *Daubentonia madagascariensis*, and, occasionally, an arboreal snake, *Ithycyphus miniatus.*

Sometimes the same name was used for different species, as was the case for *fosa varika*. One species called *fosa varika* by some interviewees, clearly *G. elegans*, was described as small and having red pelage; a second species (*C. ferox*) as larger with brown pelage. *Varika*, in other parts of Madagascar, is occasionally used as a name for larger diurnal lemurs, comparable to *akomba* and *gidro*. When used in conjunction with *fosa* at the Montagne d'Ambre, it means lemur predator. Both *C. ferox* and *G. elegans* prey on lemurs. People living around Montagne d'Ambre commonly use *akomba* rather than *varika* when referring to large diurnal lemurs such as *Eulemur sanfordi* (Freed, 1996).

Another term used by interviewees to describe multiple euplerid species was *fosa be* or "big *fosa*." It was often used for whichever species was the largest euplerid known to the interviewee. This was sometimes *C. ferox* and sometimes an animal reported as larger than *C. ferox*. Thus, to deduce the specific identity of any particular animal, we needed to examine the suite of other carnivorans that the interviewee described. For example, when an interviewee identified *C. ferox* using a name such as *fosa fangoko* or *fosa angoko* and then also distinguished this species from a much larger carnivoran (a *fosa* or *fosa be*) with pelage unlike that of *C. ferox*, we inferred that, for this respondent, the name *fosa* or *fosa be* did not refer to *C. ferox*.

Table 1 lists the multiple names used for each euplerid species in the general Montagne d'Ambre area, including the species described as bigger than *C. ferox*. Names for this big fosa included *fosa joby*, *fosa mainty*, *fosa jobijoby*, *fosa tamana*, *fosa maventy*, *fosa maventy be*, *fosa tombotomboloha*, and very rarely *fosa fangoko* or *angoko* (names more commonly used for *C. ferox*). *Joby* and *mainty* mean black; *jobijoby* means somewhat black, or blackish; *maventy* and *maventy be*, mean big; *tombotomboloha* refers to an animal that is red but darker along its back; *tomboloha* is a coat color that is, like that of some cattle, not entirely red and not entirely black; *tamana* refers to an animal that is comfortable in the habitat or region in which it lives.

Other species of carnivorans at Montagne d'Ambre are introduced; they include the small Indian civet (*Viverricula indica*, a member of the family Viverridae) and the dog (*Canis familiaris*). Dogs were often mentioned in the context of physical comparisons with euplerids or of fights between dogs and the big *fosa*. Interviewees characterized dogs as afraid of the big euplerid and as victims of fights with this animal. *Viverricula* was not described as a fosa by any respondent.

Selected accounts of a big, dangerous *fosa*

We present here excerpts from the portions of nine interviews pertaining to the animal described as the big *fosa* (three from the West, three from the Northwest, two from the Northeast, and one from the East). The Appendix provides these same excerpts (with the same identifying numbers, 1-9) in French and in the original Malagasy (taken directly from recorded interviews).

Table 1. Names for euplerids and other species used by villagers in and around the Montagne d'Ambre Massif.

Taxon	Names used at Montagne d'Ambre	Conservation status (2021 IUCN Red List)
Galidia elegans	*Fosa fitry*, *vontsira*	Least Concern
Fossa fossana	*Fosa varika*, *fosa vahy*, *fosa vary*, *fosa fangiko*, *fosa vato*	Vulnerable
Eupleres goudotii	*Fosa amboa*	Vulnerable
Cryptoprocta ferox	*Fosa*, *fosa be*, *fosa fangoko*, *fosa angoko*, *fosa varika*	Vulnerable
*A big fosa (*C. spelea*?)	*Fosa*, *fosa be*, *fosa maventy*, *fosa tamana*, *joby tombotomboloha*, *fosa joby*, *fosa mainty*, *fosa jobijoby*	Extinct
**Daubentonia madagascariensis*	*Aye-aye*, *kakahely*, *laimbolo*, *lailaimbolo*	Endangered
**Ithycyphus miniatus*	*Fandrefy ala*, *fandrefiala*	Least Concern

*Animal considered extinct, extirpated, or disappearing by at least some interviewees.

Five of these nine accounts provide sufficient detail to be considered credible eyewitness sightings. They are labeled "personal encounter," and the year and location of the sighting are provided if known. Sightings occurred periodically throughout the past half century. These include one "a long time ago" at Ankorefo in the Northwest, another in 1980 at Beanamalao in the West, one in 2000 at Sadjoavato in the East, one in 2013 at Joffreville in the Northeast, and finally, one in 2020 in the West, on the footpath between Beanamalao and Joffreville. The locations of all sightings are shown in Figure 1.

West

1) *Fosa tamana* = *Fosa be* = *Fosa* (personal encounter in 1980 at Beanamalao).
   I have seen a black fosa but they are rarely seen. They are called *fosa tamana* (the chicken thieves). The *fosa tamana* is very dangerous, and very wild. It attacks people. I last saw it when I was 16 (in 1980) when it had gotten into a fight with dogs, and I was told that it is called the *fosa*. People also call it the *fosa be* (big fosa), *fosa joby* (black fosa) or *fosa mainty* (black *fosa*). The *fosa tamana* is large; it attacks chickens and people. I am afraid of it because of its teeth and very long claws; it can scratch people. In addition to chickens, it eats puppies, calves, and even sick adult cows that it finds in the forest. It scratches their eyes.
2) In the past, there was a really dangerous *fosa*; there were many of them and they could kill people. This animal was colored like a crow: black with a white tail; the tail was very long. I have heard stories about this animal. During their mating season, when people passed by, they would become very dangerous. I'm told that the male was particularly dangerous. The breeding season is during the *lohataona* (austral spring) season during the month of October. There was a man passing through the forest; several *fosa* surrounded him and killed him.
3) *Fosa* (personal encounter in June 2020 on the footpath from Beanamalao to Joffreville). There are two types of *fosa* which are ginger and black. The two types are similar in shape but differ in size; that is the main difference. The *fosa angoko* [*Cryptoprocta ferox*] is the smaller one, and the *fosa* is the big one. Both have very long tails, short forelimbs and very long hind limbs. I last saw a *fosa* in June 2020 when I was on the footpath from Beanamalao to Joffreville. The *fosa* that I saw at that moment was the one that is very big, and I only saw one individual. He was very black. I am afraid of *fosa*, very afraid, because they are aggressive, and they chase people. They are bold enough to do this, and they bite and scratch. When they are here in the countryside, they eat poultry (chickens, ducks, and other kept birds). But when they are deep in the forest, they eat all the animals they encounter, for example lemurs, the ibis (*akoho ala*). The best time to see a *fosa* is during their mating season (October, November, and December). That is when your chances of seeing one increase.

Northwest

4) A very dangerous animal used to live here, but recently, I haven't seen it with my own eyes. I've only heard stories about it. I've heard that it was truly very dangerous, that it consumed all sorts of animals, and it even dared attack people.
5) I've heard that the *fosa* knows how to fight and that it does not fear dogs. … I am afraid of the *fosa* that is the truth. And also, in the park, I've seen the materials belonging to Ben (Ben Freed) that were destroyed by the *fosa*.
6) *Fosa* (personal encounter "long ago" at Ankorefo). There used to be a *fosa* that would attack farm animals. There are two types of *fosa*: one is small but bigger than a cat (*fosa fangoko* [=*Cryptoprocta ferox*]), and one is big, like a dog. I did see a big one, a long time ago, in a rice field at Ankorefo. It was red, but not really red – dark red, almost black; I really am at a loss to describe its color. It had short forelimbs, very long hind limbs, elevated hind quarters, a long thorax, and very long claws. It is very difficult to kill this animal. Throwing stones at it won't kill it. You must beat it with a stick. A single man alone cannot kill it; it takes 2 or 3 men to overcome him, one using a branch to disturb its eyes, because it is afraid of branches, and the others using sticks to hit him on his back.

Northeast

7) *Fosa* (personal encounter in 2013 at Joffreville). I have seen the *fosa* with my own eyes. The first time was when it attacked my chickens. It was nighttime, and it arrived to attack the birds in my chicken coop. I had 10 chickens and it had already killed four by the time I heard the noise. I opened the door to my house, and the animal exited the chicken coop when he heard me. He

began to flee with one of the chickens that he had just killed; he was not far from me, approximately 10 m. I didn't have my big knife so I picked up a stone and threw it at him. When the stone hit him, he dropped the bird. It was night but there was a full moon and he was easy to see. That was the first time that I had ever seen a *fosa*. It was in 2013, the month of November, at the CEG (Collège d'Enseignement Général).

He resembled a dog; his head, body, and tail exceeded 2 m in length, and I think he weighed between 25 and 30 kg, because he was very big. His coat was black, very black. People call this animal, simply, *fosa*.

8) The *fosa* or *fosa jobijoby* is a bit bigger and longer than a *fosa varika* (I don't know how much bigger exactly). His coat is somewhat black. Also, this one is very dangerous. He has a very long tail, and his forelimbs are very short relative to the hind limbs. His claws are very long and sharp. … I am afraid of the *fosa* because it is truly very dangerous; it scratches with his paws and bites with its mouth, and it does not retreat from people.

East

9) *Fosa* (personal encounter in 2000 at Sadjoavato). The *fosa* is big like a dog; its coat is red but its muzzle is black. Its forelimbs are short. I saw a big *fosa* when I lived at Sadjoavato. The *fosa* had stolen chickens from our chicken coop. He was the size of a dog, very large. I was perhaps 18 years old. My father and I tricked him and caught him by the throat. He had just killed around 30 chickens…. His tail was around 1.2 m long, and hairy.

Descriptions of large carnivorans at Montagne d'Ambre

Of the 90 total interviews, nearly half (42, or 47%) mentioned the existence of a large carnivoran, and 25 of these 42 (59%) specifically drew comparisons to dogs (Table 2; Figure 2). The 42 interviews that mention the existence of a large carnivoran provide a glimpse into the local shared knowledge of the big carnivoran species, i.e., which themes appear when this animal is being described, and how often does each appear.

Table 2. Summary of interview results.

Thematic element	% of 42 interviews mentioning "big" carnivoran that scored "yes" on theme	% of 25 interviews mentioning "dog-sized" carnivoran that scored "yes" on theme
Does the interviewee claim that the size of the animal is comparable to or bigger than a dog?	59	100
Does the interviewee claim to have personally seen the animal?	91	96
Does the interviewee claim that the animal has an elongated chest or trunk?	5	4
Does the interviewee claim that the animal has short forelimbs and long hind limbs?	55	56
Does the interviewee claim that the animal climbs trees?	29	32
Does the interviewee claim that the animal is found often (or entirely) in the forest?	36	36
Does the interviewee claim that the animal is dangerous?	48	44
Does the interviewee claim to be personally afraid of the animal?	69	68
Does the interviewee describe the animal as having black pelage?	21	20
Does the interviewee describe the animal as having red (reddish, ginger) pelage?	31	40
Does the interviewee describe the animal as having gray or ash pelage?	33	36
Does the interviewee describe the animal as having mottled or mixed coloration?	21	20
Does the interviewee specifically describe the muzzle as black?	5	8
Does the interviewee describe the animal as more dangerous or ferocious during the breeding season?	45	40
Does the interviewee claim the animal can kill a dog?	21	20
Does the interviewee claim the animal can kill a young or sick cow (or any cow), pig, or wild bush pig?	48	40
Does the interviewee claim the animal can kill a person?	36	36
Does the interviewee claim the animal feeds on lemurs?	31	36
Does the interviewee claim the animal raids chicken coops?	69	76

Figure 2. Comparison of humeri of dogs (*Canis familiaris*, two humeri to the left of the scale) and *Cryptoprocta spelea* (one humerus to the right of the scale). The dog bones are from a modern street dog from Antananarivo (extreme left, Académie Malgache [AM] 1254) and an uncatalogued subfossil bone from Anavoha (a paleontological site in the extreme south). The *C. spelea* humerus (Université d'Antananarivo [UA] 10563) is from a cave in southwestern Madagascar (Grotte d'Ankazoabo). Its length matches that of the larger (modern) dog from Antananarivo.

In an overwhelming percentage (91%) of these 42 interviews, the interviewees claimed to have personally seen the animal, and more than 50% claimed personal fear of the animal, that the animal raids chicken coops, and that the animal displays the body proportions of a euplerid (particularly in having short forelimbs and long hind limbs). For both *C. ferox* and *C. spelea*, the intermembral index, [(humerus + radius) / (femur + tibia)]*100, slightly exceeds 75%, whereas that of the dog *Canis familiaris* approaches 100% (Table 3). Other common themes of these interviews (though less common than the aforementioned) were that the animal is dangerous, particularly during the breeding season, and can kill large animals such as a young cow, pig, wild bush pig, person, or dog. The big carnivoran is also said to have a very long tail, an elongated trunk or thorax, and long claws. Although specific dimensions of the large carnivoran were rarely provided, some interviewees were very specific, and when dimensions were provided, those dimensions matched expectations for a very large euplerid. The tail was reported to be around three times longer than that of a large male dog from Antananarivo, and around a third longer than that of a northern male *Cryptoprocta ferox*, which also has a long tail (Table 4; Figure 3). The estimated body mass of the large euplerid is greater than a large male dog from Antananarivo, and between 200 and 300% greater than a male *C. ferox* from the north (Table 4). Body mass estimates are equal to or greater than that of that same male dog (Table 4).

Coat color was often used to distinguish species or individuals within single species; the same applied to the large *fosa*. Details of the descriptions of the pelage of the large *fosa* were not entirely consistent, except in the fact that they differed from that of *C. ferox*, which was usually said to be brown. The large *fosa* was described instead as very black, blackish, ash, gray, or red with some black (e.g., red with a black muzzle). One interviewee described seeing a pair of large *fosa*, one of which was gray and the other black, which suggests that there may have been some dichromatism.

A number of interviewees mentioned that the probability of seeing a large *fosa* increases during the breeding season. They also noted that groups of individuals can be observed at that time. Several interviewees noted that the big carnivoran is arboreal. Some interviewees noted that the large carnivoran consumes lemurs, while others note its preference for domesticated animals such as chickens. One interviewee remarked that this animal targets

Table 3. Measurements of long bones (with means and standard deviations in mm) and intermembral indices for extant Carnivora and for subfossil *Cryptoprocta spelea*.

Taxon (N for all, or for humerus, radius, femur, and tibia, respectively)	**Humerus length**	**Radius length**	**Femur length**	**Tibia length**	**Intermembral index**
Eupleridae					
Fossa fossana	75.7 ± 3.7	79.2 --	86.7 ± 6.8	94.7 ± 8.8	85.4
Cryptoprocta ferox (N = 4; this paper)	114.3 ± 3.5	89.4 ± 5.4	138.9 ± 4.2	128.8 ± 5.6	76.1
C. ferox (N = 9, 10, 11, 11; Goodman *et al.*, 2004)	116.1 ± 5.3	88.6 ± 4.1	139.2 ± 7.5	129.1 ± 6.9	76.3
C. spelea (N = 12, 7, 13, 6; this paper)	143.6 ± 5.7	107.7 ± 3.0	169.5 ± 5.4	153.5 ± 6.8	77.8
Canidae					
Canis familiaris (Detry & Cardosa, 2010)	144	154	167.5	--	--
Canis familiaris (Harcourt, 1974)	142-188	144-190	142-199	164-207	--
Canis familiaris (Onar & Belli, 2005)	180.5 ± 8.7	180.7 ± 11.7	192.9 ± 11.4	197.5 ± 12.6	92.5

Table 4. Measurements of carnivoran species represented at Montagne d'Ambre.*

Taxon	Head+body length (cm)	Tail length (cm)	Total length (cm)	Mass (kg)	Source
Galidia elegans	30-38	26-29	56-67	0.8-1.1	Goodman (2012)
Eupleres goudotii	47-52.5	20-25	67-77.5	1.6-2.1	Goodman (2012)
Fossa fossana	63-70	22-26	85-96	1.3-2.1	Goodman (2012)
Cryptoprocta ferox	70-80	65-70	135-150	5.5-9.9	Goodman (2012)
Cryptoprocta ferox ♂	79.4	66.4	145.8	7.75	Dollar (unpublished data)
Cryptoprocta ferox ♂	75.5	72.1	147.6	6.25	Dollar (unpublished data)
Cryptoprocta ferox ♀	73.5	66.9	140.4	6.1	Dollar (unpublished data)
Canis familiaris ♂	95	36	131	21	Randria (unpublished data)
Canis familiaris ♀	71	26	97	13	Randria (unpublished data)

*Previously unpublished data on *Cryptoprocta ferox* and *Canis familiaris* were collected by LJD at Ankarana and by José Narcisse Randria at Antananarivo, respectively.

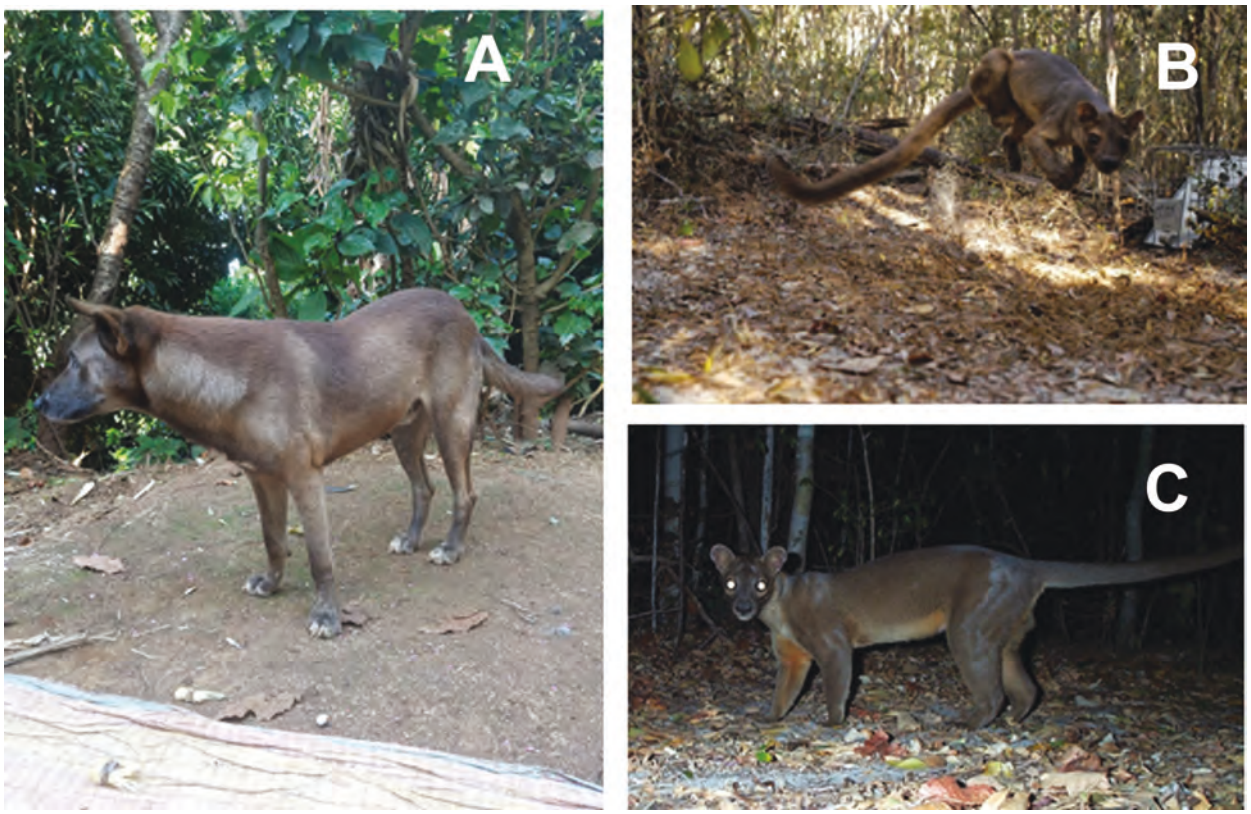

Figure 3. A) Dog (*Canis familiaris*) from Bezavona in the eastern part of the Montagne d'Ambre, northern Madagascar – lateral view. **B**) *Cryptoprocta ferox* at Ankarafantsika, leaping. **C**) Lateral view of *C. ferox* at Kirindy Mité. Note the considerably longer tail, shorter forelimbs, relatively longer hind limbs, and relatively longer trunk of *Cryptoprocta* in comparison to *Canis*. Photo by A) ESN, July 2020; B) LJD, ca. 2004; and C) LJD, ca. 2002.

domesticated animals in the countryside, and wild animals (including lemurs) in the forest.

Variation in descriptions by age, sex or region

There were no regional differences in the percentages of old (>50 years) vs. young (<50 years) individuals who mentioned the existence of a large carnivoran. Interview data revealed few differences by age of the interviewee, with several minor exceptions. The age of interviewee was significantly correlated with whether the interviewee asserted that the large carnivoran kills dogs. Older people were more likely to say they do (Spearman rho = 0.406, $P = 0.008$). Older individuals were more likely than younger individuals to describe the large carnivoran as ferocious, and to state that the animal kills domesticated animals or people, or that it is especially ferocious during the breeding season. Older individuals were more likely than younger to state that they are personally afraid of the animal. Younger people were more likely to state that the large carnivorans feed on lemurs, and that they had personally seen them.

Table 5. Percentages of 42 interviews coded "yes" for thematic element, by region within Montagne d'Ambre.

Thematic element (T)*	Northwest	East	West	Northeast
T1	83	88	100	90
T2	42	88	58	60
T3	17	0	0	0
T4	67	50	42	60
T5	8	50	42	20
T6	33	38	50	20
T7	75	63	33	20
T8	83	63	58	70
T9	8	13	25	40
T10	8	38	33	50
T11	58	38	8	30
T12	17	25	33	10
T13	0	25	0	0
T14	42	50	33	60
T15	33	13	25	10
T16	42	38	75	30
T17	42	13	50	30
T18	17	25	33	50
T19	83	75	58	60

*See Methods for list of themes 1-19.

There were also no regional differences in the percentages of males vs. females who mentioned the existence of a large carnivoran. In general, also, sex differences in interview responses were statistically insignificant, with few exceptions. Male interviewees to be more likely than females to say that the animal could kill a dog, but less likely to express personal fear of the animal. Females identified the animal as forest-dwelling more often than did males. Regional differences in the content of interviews were also minor. The four regions displayed remarkably similar profiles in their responses to coded themes 1-19 (Table 5). Every regional profile was significantly correlated with every other (Table 6). Euclidean distance analysis generated a dissimilarity matrix (larger values signal larger differences); the Northwest is the most distinctly different region from all others, and the West and Northeast are the most similar (Table 7). The Northwest is the region with the lowest percentage of the 42 interviewees who mention the existence of a large carnivoran that also mention having personally seen the animal (83% vs. anywhere from 88 to 100%). This difference is not large. Collective knowledge of a large carnivoran is consistent across all four regions. It is also noteworthy that the West and the Northeast (the two regions that are the most similar) are connected via a widely used footpath that extends from Beanamalao in the West to Joffreville in the Northeast.

Discriminant function analysis reveals the same pattern revealed by the Euclidean distance analysis; Function 1 separates the West and Northeast from the Northwest, with the East intermediate (Figure 4). Based on the coded data in the 45 interviews that specifically mention a big carnivoran, it is possible to distinguish regions with 81% correct classification, but with cross-validation, the success rate is much lower. The most important regional differences are in reports of pelage coloration. Black appears most often (but not exclusively) in the West and Northeast, the two "most similar" regions.

Finally, our coded themes themselves were generally not significantly correlated. Exceptions were a significantly positive correlation between assertions that the large carnivoran is dangerous and that is dwells in the forest (Spearman rho = 0.483, P = 0.001), and a statistically significant positive correlation between assertions that the interviewee is afraid of the animal and that the pelage of the large carnivoran is black (Spearman rho = 0.350, P = 0.02).

Table 6. Similarities between descriptions of large carnivorans across regions of Montagne d'Ambre, as indicated by highly significant correlations for coded interview themes.

		Correlations			
		West	Northwest	Northeast	East
West	Pearson Correlation	1	0.563*	0.682**	0.669**
	Sig. (2-tailed)		0.012	0.001	0.002
	N		19	19	19
Nortwest	Pearson Correlation		1	0.597**	0.675**
	Sig. (2-tailed)			0.007	0.002
	N			19	19
Northeast	Pearson Correlation			1	0.708**
	Sig. (2-tailed)				0.001
	N				19

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 7. Euclidean distance analysis of coded interview themes by region (lower numbers indicate smaller distance and thus greater similarity).

	West	Northwest	Northeast	East
West	0.000	1.054	0.854	0.865
Northwest		0.000	1.030	0.923
Northeast			0.000	0.841
East				0.000

Incorporation of mythical elements into animal stories

Mythical elements of the stories people tell are often intended to teach a lesson or provide a warning about good or bad human behavior. At Montagne d'Ambre, they appear in accounts of species with varying conservation status. This is certainly the case for stories regarding the snake (*Ithycyphus miniatus*, conservation status Least Concern), the aye-aye or the *kakahely* (*Daubentonia madagascariensis*, conservation status Endangered), and the *fosa* (*Cryptoprocta ferox* and *C. spelea*, conservation status Vulnerable and, presumably, Extinct).

One story about the *fosa* pertains to the cultural norm at the Montagne d'Ambre for suitors of young women to request the hand of a woman in marriage from the woman's parents. In this story, a *Cryptoprocta* dresses like a suitor in man's clothing and is awarded the hand of a family's youngest daughter, Benjamine. The daughter soon discovers, to her horror, that the suitor is not a man, but is, instead, a dangerous predator. The groom has fooled both the parents and the bride. The story is a warning that families must know the suitor and the region from which he comes before granting him permission to marry their daughter. He may not be as he appears.

Another story describes a *fosa* searching for water but finding, instead, in places where water was once plentiful, many houses made of dried plant materials such as leaves that burn easily and cause small fires to spread. So when the fosa sees an abandoned campfire that is still burning, he extinguishes the fire with his tail.

The *kakahely* and the aye-aye

A majority (49, or 54%) of the 90 interviewees mentioned the aye-aye (*Daubentonia madagascariensis*), which is widely perceived to be a dangerous and rare beast. Eleven of these (12% of the 90) also mentioned a beast called the *kakahely*, often perceived as even rarer, or indeed extinct. Stories of the *kakahely* have elements that almost certainly refer to the aye-aye but some incorporate attributes of a large carnivoran. Some people stated that the *kakahely* is identical to the aye-aye. Others described the two as different animals. Some treated

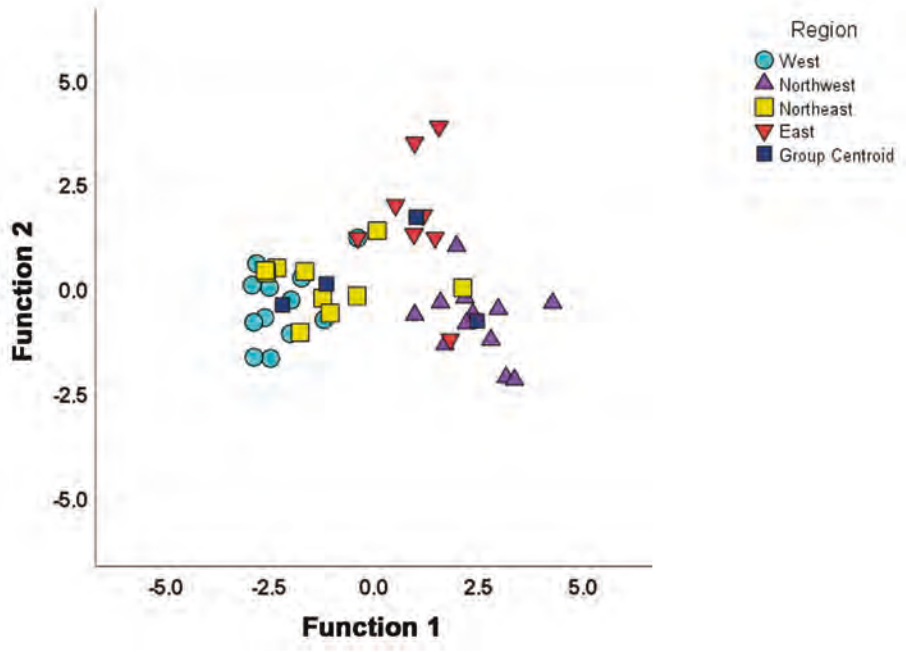

Figure 4. Discriminant Function Analysis of coded interview data for the 42 interviews mentioning a large carnivoran. Function 1 best distinguishes the regions of Montagne d'Ambre. Specifically, the West and Northeast (with largely negative scores) are contrasted with the Northwest (with largely positive scores). However, there is regional overlap in the response pattern.

Figure 5. White guard hairs occur on the shoulders and back of a living aye-aye (*Daubentonia madagascariensis*). (Photo by David Haring, Duke Lemur Center, printed with permission).

the aye-aye as real but the *kakahely* as mythical. One interviewee was sure that the *kakahely* is a type of *fosa* that is mythical or extinct. In these stories, both the aye-aye and the *kakahely* are imbued with powers that the actual aye-aye lacks, mostly related to the notion that when these creatures show up at a village, misfortune or death of a human will follow.

This animal was also described as having the power of visiting nonlethal curses on villagers, such as the curse of itchy skin. Whether this relates to the abundance of the invasive "itchy bean" plant (*tainkilotra*, or *Mucuna pruriens*) at Montagne d'Ambre and Ankarana, which somehow became associated with aye-ayes, or to some power accorded the coarse white hairs on the shoulders and the backs of aye-ayes, is unclear (Figure 5). One of the local names for this animal, the *lailaimbolo*, refers specifically to having hair that makes one scratch. The *lailaimbolo* is said to arrive at a house and shake vigorously to cloud the region with hairs that scratch and cause itching. The white hairs of the aye-aye do shed (as do the denser, softer black undercoat hairs) but they do not cause itching.

Other anatomical details provided by the interviewees are consistent with the notion that the *kakahely* is the aye-aye. Interviewees noted the size (larger than a *Eulemur coronatus* but smaller than a *Cryptoprocta ferox*), the rounded profile of the jaw, and that this animal has only four teeth, two maxillary and two mandibular. Of course, aye-ayes have more than four teeth, but given the diastemata separating the incisors from the cheek teeth, only four teeth are visible to observers of living individuals (Figure 6).

Figure 6. Four teeth are visible when viewing a living aye-aye (*Daubentonia madagascariensis*); these are the incisors. (Photo by David Haring, Duke Lemur Center, printed with permission).

Discussion

The stories people tell, when integrated with biological information from similar species, are evidence that *Cryptoprocta spelea*, presently recognized by researchers as an extinct species, may very well be extant though Critically Endangered. We are struck by the extent to which people have seen and similarly described aspects of the anatomy, behavior, and habitat selection of a large, dark carnivoran. Eyewitness reports reflect sightings of the large *fosa* from as early as 1980 through 2020. Interviewees described the size and color of the large carnivoran, sometimes contrasting these traits with those of the more common fosa (*Cryptoprocta ferox*) or with the dog (*Canis familiaris*). Whereas the smaller *fosa* was often described as brown, the larger *fosa* was usually described as dark (very black, blackish, ash, grayish, or dark red to black) and possibly varied in color. It was also described as relatively longer in body than the dog, as having a much longer tail, and as having limb proportions like those of the smaller *fosa* (with relatively short forelimbs and long hind limbs, resulting in a head held low and back inclined upward from front to back). The size estimates of local people and from Freed matched expectations for *C. spelea* and differed greatly from what we know is true of *C. ferox*. The size matched (or slightly exceeded) that of large male dogs, but the proportions differed. It is worth noting that the head-and-body length of the individual observed by Freed was at least a third greater than that of *C. ferox*, and greater than that of large male dogs from Antananarivo. In most cases,

eyewitnesses reported being afraid or considered this *fosa* to be dangerous, given its size and long claws.

Local descriptions of the large *fosa* as a lemur predator also match well with expectations based on anatomical evidence. The morphology of the long bones of *C. spelea* reveals its locomotor adaptations, and it is clear from a host of traits (for example, the posteromedially-expanded medial epicondyle of the humerus) that this was an animal capable of climbing trees, despite its large size (Meador *et al*., 2019; Lewis *et al.*, unpublished data). Animals that cannot climb trees, such as dogs, have small posteriorly-directed medial epicondyles (Meador *et al*., 2019) (Figure 2). There is also direct evidence of lemur consumption by large-bodied *C. spelea* in the fossil record (Meador *et al*., 2019). *Cryptoprocta ferox* is normally a lemur predator, but it has recently become a notorious seasonal raider of chickens and is thus widely viewed as a pest (Borgerson, 2016; Borgerson *et al*., 2019).

Local descriptions of the large *fosa*'s behavior versus dogs differ greatly from reports of other *fosa* populations. Interviewees noted that the larger *fosa* shows no fear of dogs. In at least two eyewitness accounts, the larger *fosa* had raided domesticated birds, and did not fear dogs. A larger *fosa* with no fear of dogs would not need to avoid areas where dogs are present. Dogs may, however, sound an earlier alarm if *fosa* are in the area. In contrast, researchers elsewhere in Madagascar have shown that populations of *C. ferox* tend to decline when dogs are introduced or present in an area (Barcala, 2009; Farris *et al*., 2017). On the basis of limited overlap in stable isotope values between dogs and *C. ferox*, Hixon *et al*. (2021) suggest that chasing and exclusion competition explain the negative interaction between dogs and *C. ferox* better than exploitation competition.

Interviewee observations of when *fosa* are most likely seen near humans match well with behavioral expectations based on *C. ferox*. Although interviewees stated that *fosa* generally are most likely seen during mating season in late September through November, several eyewitness accounts of the large *fosa* occurred outside of that season, including in June and December. During most of the year, *C. ferox* are solitary except when young siblings likely disperse together. This changes during the mating season, which apparently for both *C. ferox* and the larger carnivoran, is at the end of the dry season and beginning of rainy season (late September through early or mid-November). *Cryptoprocta ferox* males gather around a female's mating tree at that time, and this is the most likely time for anyone to see this species (Hawkins & Racey, 2009).

We identified five credible personal encounters by interviewees (in addition to the one experienced by BZF). These encounters span a period of 40 years and in different areas of the Montagne d'Ambre Massif. These supplement BZF's account of his sighting in 1989 at Ampamelonabe in the West. The local people of Montagne d'Ambre described the large *fosa* as rare or perhaps recently extinct. While some researchers may view these eyewitness reports with skepticism, their uniformity must be appreciated. Based on these eyewitness accounts, we infer that the large *fosa* likely had a broad recent distribution within the Montagne d'Ambre, i.e., in the West, Northwest, Northeast, and in a riverine forest that connects to the East. Most of these sightings are from regions within 2 km of forest edge habitat, and several accounts include the raiding of local domesticated animals. About half of all interviewees reported having heard stories of this larger *fosa*, no matter the region. Based on these encounters and interviews, we believe that the larger *fosa*, if it still exists in Montagne d'Ambre, is most likely Critically Endangered.

We had expected that regional differences would occur in people's descriptions of the wildlife. This is because regional differences do occur in terms of road access, extent of agriculture and forest cover, and conservation threats. Despite this, we found few significant differences in interview responses due to forest region. Anatomical and behavioral descriptions of the animals were consistent. Interviewees also brought the same mythical themes into their descriptions. Mythical themes included fantastic elements that could not be true but were nevertheless consistently retold. To us, it matters not whether a *fosa* could possibly put out a campfire by beating it with its tail. We are instead struck by the uniformity of the descriptions of this tale, and the willingness of people to incorporate local wildlife into folklore, all of which we view as evidence of human interaction with the environment. The *fosa* in the campfire tale also informs and helps regulate human actions (to put out campfires), lest one angers the *fosa*.

All elements of traditional knowledge, reflected by anatomical and behavioral descriptions, together with mythical elements, are vital to our understanding of local wildlife. Collective oral memory and "traditional

ecological knowledge" (TEK) have been applied to many critical aspects of biological conservation, providing researchers and conservationists with details that may reflect important information regarding a species' behavior and ecology, and may significantly improve the success of a conservation program (Berkes *et al*., 2000; Colchester, 2004; Schmidt & Peterson, 2009; Wheeler & Root-Bernstein, 2020). Many real species are incorporated by local people into a region's oral history. Although many researchers have dismissed local animal descriptions that include mythical themes, it is usually not difficult to tease these apart from more traditional anatomical and behavioral descriptions. More importantly, mythical themes may have great value to local people. The presence of mythical themes can serve as an indication of local people's engagement in conservation and regard for nature (Nkwi, 2017). Mythical themes and biological elements often combine and may serve as important indicators of local history and about a species' biology and habitat selection. Reynolds & Romano (2013) showed how tribal oral histories revealed great detail regarding a threatened fish species' behavior and biology.

Our research on traditional ecological knowledge at Montagne d'Ambre concords with research on the same subject from elsewhere in Madagascar. Hume (2012) showed that local farmers in Madagascar rely on extensive knowledge of their surrounding environment. Holmes *et al*. (2018) reviewed several mythical elements of local stories about animals in Tanzania and Madagascar, including aye-ayes, snakes, and other very real and, in some cases, threatened species. In Montagne d'Ambre, we reported similar mythical stories about aye-ayes (*kakahely*) and other species, including a larger- and a smaller-bodied *Cryptoprocta*. From our own observations, we recognize other fantastic elements in stories about local lemurs, chameleons, and other endangered wildlife. In the case of the large *fosa*, people reported it as impersonating humans, as putting out fires, and more. The fact that the aye-aye and the *fosa* cannot perform some of the tasks attributed to them does not diminish the fact that local people recognize these animals and have preserved them in both folklore and in eyewitness accounts. The stories people tell point to traditional ecological knowledge, and may serve as vital information that should lead to future directions of research and conservation. The existence of mythical elements in the stories in no way lessens this potential.

When these stories, eyewitness accounts, and research are combined, they may offer Madagascar's conservationists information critical to prioritizing particular remote regions for targeted surveys, on the remote possibility that a "rare" or indeed "extinct" species may be discovered there. Effective conservation demands involvement of local people and community buy-in (Gezon & Freed, 1999; Schellnack-Kelly 2017). It requires collaboration. Local people should be sought to contribute their oral histories and knowledge. This can bring about better local engagement with external efforts to conserve endangered flora and fauna (e.g., Wedemeyer-Strombel *et al*., 2019). The future of field science would benefit not merely from community permission, but greater community involvement, with mutual knowledge-sharing and genuine collaboration in establishing short and long-term goals (see Douglass *et al*., 2019, on community involvement in archaeology). Stories, histories, research, and the people who tell them, matter.

Conclusion

This collection of eyewitness accounts and oral histories about the wildlife of Montagne d'Ambre provides information that requires further investigation about a species (cf. *Cryptoprocta spelea*) whose status is in question. We argue that true understanding of this and other Malagasy species' conservation will be brought to greater clarity with a multidisciplinary approach that includes (among others): biological surveys, observations, and genetic information; historical, paleontological, and archaeological input; botanical and forestry data; geographic and remote sensing data; and sociocultural information. None of this would be possible without researchers working with and including local people, both for the collection of important information and for the implementation of effective conservation policy.

Cryptoprocta spelea may or may not be extinct today. If it is still extant, we argue that it may occur at least in the region of Montagne d'Ambre, and possibly in some of the most stable riverine forests that extend from it. Ultimately, while corroboration through camera traps or molecular sequencing of recovered scats may be possible, embracing collective oral memory and gathering more input from local people are imperative. We hope that local traditional ecological knowledge from throughout Madagascar will reveal greater understanding about the people and the nature of the island.

Acknowledgements

For the research led by ESN in 2020, we thank Brigitte Marie Raharivololona (Chef de la Mention Anthropobiologie et Développement Durable, Université d'Antananarivo) for her support and approval to conduct this research. For permission to conduct the research in the field, we thank Mrs. Odile Venty of Madagascar National Parks and Director of Montagne d'Ambre National Park; the president of the Fokontany Joffreville, her assistant, and the headmistress of CEG Joffreville; the President of Fokontany Beanamalao; the forest agent, the President of the Fokontany and the entire CLP (Comité local du Parc) from Bobakilandy; the President of the Fokontany Antsalaka; the President of the Fokontany Ankorefo; the sector chief of Anjavy and Bezavona; and the entire CLP from Anjavy and the communal agent. We are grateful for the support of the two forest agents of MNP (Madagascar National Parks) in Andranotsimaty, and the two forest agents of MNP in Antombato. We very much appreciate the help of our local guide Louis Philippe d'Arvisenet and field assistant Freeman Grégory Relina, both of whom assisted with the interviews. We thank José Narcisse Randria for measuring his dogs in Antananarivo.

Funding for research in 1989-1991 by BZF was provided by: National Science Foundation grant BNS 8722340, a Fulbright Collaborative Research Grant, Boise Fund, and Sigma Xi. Research by BZF in 2004-2010 was supported by Eastern Kentucky University, Emory University, a Canadian Social Science & Humanities Research Council (2010, Andrew Walsh & Ian Colquhoun, PIs), and a National Geographic Society award (2004, Lisa Gezon & Glen Green). Support in Madagascar came from Eaux et Forêts, ANGAP/Madagascar National Parks, the University of Antsiranana (UNA), especially Professor Alex Totomarovario, and MICET, especially Benjamin Andriamihaja. Local research since 2004 was facilitated by Louis Philippe d'Arvisenet.

Field research for LJD between 1996 to present has been in part funded by the Naples Zoo, Earthwatch Institute, National Geographic Society, The Rasmussen Foundation, The Greenback Fund, and private donors. Paleontological field work by LRG and others that resulted in the discovery of new specimens of *Cryptoprocta spelea* at Tsimanampesotse National Park in southwestern Madagascar, as well as comparative research on the morphology and metrics of *C. spelea* vs. *C. ferox*, was funded in part by National Science Foundation BCS 1750598 to LRG.

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Appendix: Interview excerpts in French and official Malagasy

West

1) « *J'ai déjà vu un fosa noir, mais c'est rarement qu'on peut le voir, la dernière fois que je l'ai vu c'était quand je n'avais pas encore eu d'enfant, à peu près âgé de 16 ans (en 1980), je l'ai rencontré quand il s'est battu avec des chiens, on m'avait dit que c'était cela ce qu'on appelait un fosa.* »

   « *Celle qu'on appelle fosa tamana est de grande taille, il attaque (chasse) les poules …. Le fosa tamana attaque des personnes, mange des personnes, très sauvages, et j'ai peur de celui-ci parce qu'il a des dents, ses ongles sont très longs, et il peut nous griffer. Autre que les poules, ils mangent de jeunes chiens, de bouvillons, il griffe même les yeux des bœufs malades qu'ils trouvent dans la forêt.* »

   « *Efa nahita fosa joby na fosa mainty aho, fa mahalankalana ny ahitana ilay 'joby.' Tamin'izaho mbola tsy nanana anaka izy izay. Teo amin'ny faha 16 taonako teo izay no nahitako azy farany. Hitako niady tamin'ny alika ilay izy. Notenenin'ny olona niaraka tamiko hoe : iny izany atao hoe fosa izany.*

   Ilay antsoina hoe fosa tamana ngeza vatana, mihaza akoho… Ilay fosa tamana io manafika olona, mihinana olona, tena masiaka be. Atahorako io karazany iray io satria izy misy nify, ny hohony na angofony lava be, afaka mandrangotra. Ankoatran'ny akoho, mbola mihinana zanak'alika, zanak'omby, na dia omby marary any anaty ala ary mbola rangotiny ny masony. »

2) « *Le fosa que je connais est noir, la queue est blanche et très longue, sa coloration ressemble à un corbeau. Et il peut nous tuer. Une histoire que j'ai entendue des personnes. Avant, le fosa était vraiment dangereux. Quand c'est la période d'accouplement et que tu passes, et qu'ils sont si nombreux, ils peuvent te battre. C'est le mâle qui est le plus dangereux d'après ce qu'on m'avait dit. La période de reproduction est pendant le printemps ou lohataona, durant le mois d'octobre. Il y avait un homme qui passait dans la forêt, ils l'ont entouré et l'ont tué.* »

   « *Ohatran'ny lokon'ny goaika ny lokon'ny fosa fantatro. Mainty ny lokony, fotsy ny rambony ary lava be. Efa naheno tantara tamin'ny olona aho hoe, tamin'ny andro taloha izany hono ny fosa* « *masiaka be* », *indrindra fa rehefa manara-baviny izy ireo ary maromaro. Afaka miady amin'olona ireo. Ny lahin'izy io izany no tena masiaka. Mandritra ny lohataona ireo no manara-baviny, volana oktobra. Efa nisy izany olona nandalo tao anaty ala, nitangoronan'ny fosa, dia maty.* »

3) « *Je connais seulement deux types de fosa, il y a ceux qui sont roux, et ceux qui sont noirs, un dont on appelle juste fosa, et l'autre, on l'appelle fosa angoko [Cryptoprocta ferox], qui est un peu plus petit. Ce qui fait leur différence, c'est que l'un est très grand, et l'autre petit. C'est-à-dire, qu'ils sont tous des fosa, mais l'un est un peu court et l'autre très long. Leur queue est très longue, leurs pattes avant sont courtes, mais robustes, et la partie postérieure très haute. La dernière fois que j'ai vu cet animal, était en juin 2020, quand j'étais allé à Joffreville (sur le chemin de Beanamalao vers Joffreville). Il était très noir, le fosa que j'ai vu à ce moment-là était celui de très grande taille, c'était seulement un que j'ai vu. J'ai peur du fosa, j'en ai vraiment peur, parce qu'il est méchant, et il poursuit les hommes. Il ose poursuivre les hommes, il mord et il griffe. Quand il se trouve ici dans la campagne, il mange les volailles (poules, oiseau, et canard). Mais quand il se trouve au fin fond de la forêt il mange tous les animaux qu'il rencontre, par exemple lémurien, poule sauvage …* »

   « *Fosa karazany roa ihany no fantatro, misy ilay karazany maka loko volon-tany, ary misy mainty. Misy an'ilay iray atao hoe fosa fotsiny ny anarany, dia avy eo misy ilay iray antsoina hoe fosa angoko izany ny anarany, kelikely izay izy. Ny manavaka an'ireo ny iray ngeza be, ny iray madinidinika. Izany hoe samy fosa ihany ireo fa ny iray somary kanakana fohifohy, ny iray lava be. Izy lava rambo, ny tanany fohy fa saingy ngeza, ny vodiny avo be. Tamin'ny volana jona 2020 andro nandehanako tany Joffreville (Lalana Beanamalao mandeha Joffreville) no nahitako fosa farany. Mainty be ilay izy, ny hitako tamin'izay ilay ngeza be ireny. Iray ihany no hitako tamin'izay. Matahotra fosa aho, tena matahotra, satria io masiaka, manaraka olona. Mahasahy manaraka olona foana io, ary manaikitra dia mandrangotra. Izy io rehefa aty ambanivohitra ohatran'izao ohatra mihinana akoho amam-borona (akoho, vorona, dokotra…). Fa rehefa any anaty ala be any izy mihinana izay biby mifanojo aminy ohatra hoe akomba (gidro), akoho ala,…* »

Northwest

4) « *On disait qu'il fût un temps où il y avait un animal très dangereux, mais je ne l'avais jamais vu. C'est seulement par les histoires que je le connais, qu'il était vraiment très dangereux, il mangeait toute sorte d'animaux, et il osait attaquer les hommes.* »

   « *Tamin'ny andro taloha izany nisy biby nasiaka be. Fa nanomboka tamin'ny fotoana niainako ka hatramin'izao fotoana mbola tsy nahita maso aho. Tantara ihany no henoko, nahaizako an'ilay izy. Ny henoko hoe nasiaka be izany ilay izy ary nihinana karazana biby maro, na olombelona ary sahiny notafihana.* »

5) « *L'histoire que j'ai entendue c'est que le fosa sait se battre et qu'il n'a pas peur des chiens…. … J'ai peur du fosa, c'est la vérité. Et aussi, j'ai vu dans le parc, les matériels de Ben [=Ben Freed] qui ont été détruit par le fosa ….* »

   « *Ny tantara mikasika ny fosa henoko dia hoe mahay miady izy, ary tsy matahotra alika. Izaho matahotra fosa, izay no marina. Ary koa, efa hitako tao anaty ala ireo fitaovan'i Ben (Ben Freed) izay nopotehan'ny fosa.* »

6) « *Il y avait eu un fosa qui attaquait les élevages à Ankorefo, dans les rizières. C'était il y a longtemps.*

Je ne sais pas vraiment différencier la couleur, la forme est comme celle d'un chien, c'est comme si c'est rouge, mais pas vraiment rouge, mais comme noire, rouge virant aux noires, je ne sais pas vraiment comment définir la couleur. Il y a un fosa de petite taille, dont les gens appellent fosa fangoko un peu plus grand par rapport au chat. Et l'autre est de très grande taille, comme les chiens, mais les pattes avant sont courtes, et les pattes arrière très longues, et le tronc est très long. Les griffes sont très longues. Il est difficile de les tuer ; si on les jette des pierres, cela ne les tue pas. Une frappe à l'aide d'un bâton peut les tuer. Un homme seul n'arrivera pas à tuer un fosa, il faut être deux ou trois ; l'un peut le déranger en agitant une branche devant ses yeux parce que c'est la seule chose dont il a peur, et l'autre le frappera à l'aide d'un bâton sur le dos. »

« *Efa nisy fosa nanafika ny biby fiompy taty Ankorefo, teny an-tanimbary, efa ela be izy izay. Ny lokony tsy dia haiko tsara ny manavaka azy, ny vatany ohatran'ny vatan'ny alika, ohatran'ny menamena tsy mena tsara be fa ohatran'ny maintimainty, mena manompy mainty, tsy dia aiko tsara ny hiteny ny lokony. Misy fosa madinika iray, izay ataon'olona hoe* « *fosa fangoko* » *madinika, lehibebe raha ampitahaina amin'ny saka. Ny iray ngeza be, mitovy amin'ny alika fa izy fotsiny ny tanany fohy, ny tongony avo be ary ny vozony lavalava, tsy mitovy amin'ny vozon'ny alika. Ny hohony lava be. Sarotra be ny hamonoana azy, raha toraka fotsiny tsy mahafaty azy. Kapoka no mahafaty azy. Raha olona iray tsy mahafaty azy fa mila misy olona roa na telo, ny iray mampiasa firitsoka manelingelina ny masony fa iny ihany ny zavatra atahorany, ny iray mikapoka azy amin'ny lamosiny.* »

Northeast

7) « *J'ai déjà vu de fosa, de mes propres yeux. La première fois que je l'ai vu, c'était quand il s'attaquait à mes poules. C'était la nuit, il venait s'attaquer à mes poules dans le poulailler. Mes poules étaient 10 et il avait déjà tué quatre. Quand je l'avais entendu, je suis sorti, et quand il entendait la porte s'ouvrir, il sortait aussi. Et il s'était enfui en emmenant l'une des poules qu'il avait tuées, pas loin, mais à peu près à 10 m. Je n'avais pas mon grand couteau, alors j'ai pris une pierre et je l'ai jeté sur lui. Quand je l'ai touché, il avait laissé l'autre poule. C'était la nuit, mais c'était clair, ce n'était pas sombre, mais en pleine lune. C'était la première fois que j'avais vu un fosa. C'était en 2013, un mois de novembre. Ici dans le CEG. Il ressemblait à un chien, la longueur avec sa queue était de plus de 2 m, son poids était à peu près 25 kg à 30 kg, je crois, car il était très grand. Son pelage était noir, très noir. On l'appelle juste fosa.* »

« *Efa nahita maso fosa aho. Tamin'ny voalohany nahitako azy, nanafika ny akohoko. Andro alina tamin'izay, tonga nanafika ny akohoko tao anaty rova izy. 10 ny akohoko tamin'izay ary efatra ny efa matiny. Rehefa henoko ilay izy, dia nivoaka aho, rehefa henony aho nanokatra varavana dia nivoaka koa izy. Nandositra izy ary nentiny ny iray tamin'ilay akoho novonoiny. Tsy nandositra alavitra izy fa teo amin'ny 10 m teo. Tsy taty amiko ny antsy beko, ka nalaiko ny vato ary notorahiko izy. Rehefa voatoraka izy, dia navelany ilay akoho iray. Alina ny andro tamin'izay fa ny volana nazava tsara, diavolana. Tamin'izay no nahitako fosa voalohany. Tamin'ny 2013 izy izay, volana novambra. Tato amin'ny CEG (Collège d'Enseignement Général). Nitovitovy tamin'ny alika ilay izy. Ny halavan'ny vatany miaraka amin'ny rambony maherin'ny 2 m, ny lanjany eo amin'ny 25 kg ka hatramin'ny 30 kg eo, satria tena ngeza be izy izay. Ny lokony mainty, tena mainty be. Fosa fotsiny no fiantsoanay azy.* »

8) « *Il est un peu plus grand que le fosa varika et jobijoby : noirâtre, aussi il est un peu long, je n'ai pas eu la référence exacte, mais il est un peu plus long que le fosa varika et un peu plus grand. La queue des fosa est très longue, et la partie antérieure est très basse par rapport à la partie postérieure. Leurs ongles sont très longs et pointus …. J'ai peur du fosa, parce qu'il est vraiment très dangereux, ses pattes griffent et sa bouche mord, si c'est un homme, il ne recule pas.* »

« *Lehibebe ny vatany raha mitaha amin'ny fosa varika, maintimainty 'jobijoby' ny lokony ary lavalava kely ny vatany. Tsy haiko ny tena refiny marina, fa fotsiny hoe lavalava kely izy raha ampitahana amin'ny fosa varika ary izy ngezangeza vatana ihany koa. Ny rambon'ny fosa lava be, ary somary ambany ny tanany, ny vodiny somary avoavo. Ny hohony lava be, ary koa maranitra. Izaho matahotra fosa, satria izy tena masiaka be, ny tanany mandrangotra ary ny vavany manaikitra, raha olona tsy mampihemotra azy.* »

East

9) « *Le grand fosa, grand comme un chien, de coloration rouge avec museau noire et des pattes avant courtes.* »

« *Le moment où j'ai vu un grand fosa pour la dernière fois, ce fut quand j'étais à Sadjoavato, il avait volé nos poules dans le poulailler, sa taille était comme celle d'un chien, très grand. Peut-être que j'étais âgé de 18 ans. Mon père et moi l'avions piégé et il a été touché à la gorge. Il a tué à peu près 30 poules à ce moment-là. … Sa queue était aux environs de 1,20 m, et elle était poilue.* »

« *Ilay 'fosa maventy' ngeza ohatran'ny alika, ny lokony mena, ny vavany mainty ary ny tanany fohy.* »

« *Tamin'izaho mbola tany Sadjoavato no nahitako ilay fosa maventy farany. Nangalatra ny akohonay ilay fosa tamin'izay. Ny habeany ohatran'ny alika, ngeza be. Tamin'izaho teo amin'ny 18 taona teo izay. Nofandrihanay sy dadanay ilay fosa, voa teo amin'ny tendany ilay izy. Akoho efa mandeha 30 no novonoin'ilay fosa tamin'izay, dia maty daholo. Ny rambony teo amin'ny 1,20 m, sady volovoloina be.* »