A New Species in the Genus Cheirogaleus (Cheirogaleidae)

Authors: Runhua Lei, Adam T. McLain, Cynthia L. Frasier, Justin M. Taylor, Carolyn A. Bailey, et. al.

Source: Primate Conservation, 2015(29) : 43-54

Published By: Conservation International

URL: https://doi.org/10.1896/052.029.0103
A New Species in the Genus Cheirogaleus (Cheirogaleidae)

Runhua Lei†, Adam T. McLain†, Cynthia L. Frasier†, Justin M. Taylor†, Carolyn A. Bailey†, Shannon E. Engberg†, Azure L. Ginter†, Stephen D. Nash2,3, Richard Randriamampionona4, Colin P. Groves5, Russell A. Mittermeier1 and Edward E. Louis, Jr.1,4

1Grewcock Center for Conservation and Research, Omaha’s Henry Doorly Zoo and Aquarium, Omaha, NE, USA
2Department of Anatomical Sciences, School of Medicine, Stony Brook University, Stony Brook, NY, USA
3Conservation International, Arlington, VA, USA
4Madagascar Biodiversity Partnership, Manakambahiny, Antananarivo, Madagascar
5School of Archaeology and Anthropology, Australian National University, Canberra, ACT Australia

Abstract: The genus Cheirogaleus, the dwarf lemurs (Infraorder Lemuriformes), has been identified as harboring cryptic species diversity. More comprehensive fieldwork combined with improvements in genetic research has revealed a larger radiation of species than was initially described in a number of lemur genera, including Avahi, Lepilemur, Microcebus, and Mirza. Available genetic and morphological evidence suggests that Cheirogaleus is among the genera where diversity was previously underestimated, and additional fieldwork may reveal even more species. A population of Cheirogaleus from northern Madagascar in and around Montagne d’Ambre National Park, surveyed during an expedition in 2005, was recently identified and proposed as a new species. Additional specimens were obtained during fieldwork in February of 2015. Subsequent genetic and morphological analyses of the data collected have determined that this population is an independent lineage, and herein we describe this new species, which we name Cheirogaleus andysabini after New York philanthropist Andy Sabin.

Key Words: Cheirogaleus, cryptic species, dwarf lemurs, Madagascar, new species

Introduction

The dwarf lemurs (genus Cheirogaleus) are a radiation of small, arboreal primates endemic to the island of Madagascar (Mittermeier et al. 2010). The taxonomy and species status in Cheirogaleus has been contentious; a situation exacerbated by the limited number of specimens available for study in collections (Schwarz 1931; Groves 2000; Lei et al. 2014). Groves (2000) recognized seven Cheirogaleus species (C. major, C. medius, C. crossleyi, C. adipicaudatus, C. sibreei, C. ravus, and C. minusculus); a number that has been challenged as overly conservative in recent fieldwork and genetic analyses, suggesting a larger radiation in this genus (Hapke et al. 2005; Groeneveld et al. 2009, 2010; Thiele et al. 2013; Lei et al. 2014).

Concerns about overenthusiastic species descriptions in the lemuriform radiation raised by Tattersall (2007, 2013) have been addressed previously in Lei et al. (2014). Application of the Phylogenetic Species Concept and access to data from molecular technology (Eldredge and Cracraft 1980; Wheeler and Platnick 2000) has nearly tripled the number of recognized lemur species since the early 1980s (36 to >103; Tattersall 1982; Mittermeier et al. 2010). Cheirogaleus has not experienced the type of genus-level expansion seen in Lepilemur (Louis et al. 2006) or Microcebus (Mittermeier et al. 2010); genera with the greatest increases in recognized species diversity. Nevertheless, Cheirogaleus appears to be harboring greater diversity than previously suspected (Thiele et al. 2013; Lei et al. 2014).

A new species of Cheirogaleus was identified via extensive fieldwork in and around Montagne d’Ambre National Park (Fig. 1) in November of 2005 (Lei et al. 2014), with additional fieldwork in February of 2015. The massif of Montagne d’Ambre is of volcanic origin (Segalen 1956), and this rain forest ecotype may have been separated from the surrounding dry deciduous vegetation for millions of years (Raxworthy and Nussbaum 1994), with the last volcanic eruptions occurring as recently as 2 mya (DuPuy and Moat 1996). It has a distinctive microclimate that is in part the result of greater than average precipitation in comparison to the surrounding areas. Raxworthy and Nussbaum (1994) noted the presence of species there that were altitudinal specialists, with those above 900 m living in moist rainforest, and those below 900 m living in a transitional area with a dry deciduous forest. Montagne d’Ambre’s combination of geology and climate has resulted in a unique community of microendemic fauna and flora; plants (Mathieu 2003; Callmander et
amphibians (D’Cruze et al. 2010; Rakotoarison et al. 2015), reptiles (Raxworthy and Nussbaum 1994; D’Cruze et al. 2008; Glaw et al. 2009; Ratsoavina et al. 2011), birds (Wilmé 1996), and mammals (Louis et al. 2008; Goodman et al. 2015).

The first herpetological survey in the area of Montagne d’Ambre was carried out in 1893, and subsequent expeditions have cataloged the regional endemism of the park and surrounding area (D’Cruze et al. 2008). The national park and surrounding region continues to be an exciting source of new species, including a chameleon in the genus Furcifer (Glaw et al. 2009). The area is also home to a number of lemurs, including two species in the genus Eulemur (E. coronatus and E. sanfordi), the Montagne d’Ambre fork-marked lemur (Phaner electromontis), the aye-aye (Daubentonia madagascariensis), and the recently described Montagne d’Ambre mouse lemur (Microcebus arnholdi Louis et al., 2008). Malagasy endemic carnivores are also found in the park, including the rare falanouc (Eupleres goudotii) and the ring-tailed mongoose (Galidia elegans) (Mittermeier et al. 2010).

The area around Montagne d’Ambre National Park and the Forêt d’Ambre Special Reserve were initially protected in the 1920’s as a forest station called ‘Les Roussettes’. In 1958, Montagne d’Ambre became the first national park created in Madagascar, and the Forêt d’Ambre S.R. was created the same year (Raxworthy and Nussbaum 1994). Subsequent deforestation has reduced the size of both the national park and the special reserve, in particular impacting the lowland rainforests (those below 900 m). More than twenty years ago, Raxworthy and Nussbaum (1994) observed a noticeable difference in forest cover based on a comparison of aerial photographs from the 1950s and the early 1990s. Ongoing deforestation has since been noted by Glaw and Vences (2007) and D’Cruze et al. (2008), among others.

Montagne d’Ambre National Park, like much of the remaining forested areas of Madagascar, is under the greatest threat from a combination of slash-and-burn agriculture (tavy) and charcoal extraction (Nicoll and Langrand 1989). The growth of the nearby port city of Antsiranana (formerly Diego Suarez) has accelerated deforestation by greatly increasing the demand for charcoal, a primary source of fuel for cooking. The town of Joffreville, named for the French General Joseph Joffre of First World War fame and located just east of the national park, is a center of charcoal extraction. As of 2001, 98% of the population of Joffreville was employed primarily in agriculture, with 90% farming and 8%
Table 1. Free-ranging *Cheirogaleus* samples used in this study. IDs correspond to Figure 2 and Figure 5 (Lei et al. 2014), with the exception of the samples from Thiele et al. 2013 (denoted at the bottom of the table, as well as on the map).

<table>
<thead>
<tr>
<th>ID</th>
<th>Species designation</th>
<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMB5.22</td>
<td>C. sp. nov. 1</td>
<td>Montagne d’Ambre</td>
<td>-12.52731</td>
<td>49.17331</td>
</tr>
<tr>
<td>AMB5.23</td>
<td>C. sp. nov. 1</td>
<td>Montagne d’Ambre</td>
<td>-12.53017</td>
<td>49.17464</td>
</tr>
<tr>
<td>AMB5.27</td>
<td>C. sp. nov. 1</td>
<td>Montagne d’Ambre</td>
<td>-12.51722</td>
<td>49.1795</td>
</tr>
<tr>
<td>AMB5.28</td>
<td>C. sp. nov. 1</td>
<td>Montagne d’Ambre</td>
<td>-12.47881</td>
<td>49.21222</td>
</tr>
<tr>
<td>AMB5.29</td>
<td>C. sp. nov. 1</td>
<td>Montagne d’Ambre</td>
<td>-12.47922</td>
<td>49.21606</td>
</tr>
<tr>
<td>AMB5.30</td>
<td>C. sp. nov. 1</td>
<td>Montagne d’Ambre</td>
<td>-12.47917</td>
<td>49.21597</td>
</tr>
<tr>
<td>AMB5.31</td>
<td>C. sp. nov. 1</td>
<td>Montagne d’Ambre</td>
<td>-12.51083</td>
<td>49.19275</td>
</tr>
<tr>
<td>AMB5.32</td>
<td>C. sp. nov. 1</td>
<td>Montagne d’Ambre</td>
<td>-12.51242</td>
<td>49.18956</td>
</tr>
<tr>
<td>AMB5.34</td>
<td>C. sp. nov. 1</td>
<td>Montagne d’Ambre</td>
<td>-12.47822</td>
<td>49.21717</td>
</tr>
<tr>
<td>AMB5.35</td>
<td>C. sp. nov. 1</td>
<td>Montagne d’Ambre</td>
<td>-12.49519</td>
<td>49.20783</td>
</tr>
<tr>
<td>ANJZ1</td>
<td>C. crossleyi</td>
<td>Anjozorobe</td>
<td>-18.4775</td>
<td>47.93812</td>
</tr>
<tr>
<td>ANJZ2</td>
<td>C. crossleyi</td>
<td>Anjozorobe</td>
<td>-18.4775</td>
<td>47.93812</td>
</tr>
<tr>
<td>ANJZ3</td>
<td>C. crossleyi</td>
<td>Anjozorobe</td>
<td>-18.4775</td>
<td>47.93812</td>
</tr>
<tr>
<td>JOZO4.7</td>
<td>C. crossleyi</td>
<td>Anjozorobe</td>
<td>-18.46789</td>
<td>47.94131</td>
</tr>
<tr>
<td>JOZO4.8</td>
<td>C. crossleyi</td>
<td>Anjozorobe</td>
<td>-18.46789</td>
<td>47.94131</td>
</tr>
<tr>
<td>JOZO4.9</td>
<td>C. crossleyi</td>
<td>Anjozorobe</td>
<td>-18.46789</td>
<td>47.94131</td>
</tr>
<tr>
<td>JOZO4.10</td>
<td>C. crossleyi</td>
<td>Anjozorobe</td>
<td>-18.46789</td>
<td>47.94131</td>
</tr>
<tr>
<td>MIZA16</td>
<td>C. crossleyi</td>
<td>Maromizaha</td>
<td>-18.97375</td>
<td>48.46461</td>
</tr>
<tr>
<td>MIZA19</td>
<td>C. crossleyi</td>
<td>Maromizaha</td>
<td>-18.97067</td>
<td>48.46431</td>
</tr>
<tr>
<td>MIZA6.1</td>
<td>C. crossleyi</td>
<td>Maromizaha</td>
<td>-18.95694</td>
<td>48.49236</td>
</tr>
<tr>
<td>MIZA6.2</td>
<td>C. crossleyi</td>
<td>Maromizaha</td>
<td>-18.95694</td>
<td>48.49236</td>
</tr>
<tr>
<td>MIZA7.1</td>
<td>C. crossleyi</td>
<td>Maromizaha</td>
<td>-18.95694</td>
<td>48.49236</td>
</tr>
<tr>
<td>TAD4.10</td>
<td>C. crossleyi</td>
<td>Mantadia</td>
<td>-18.80942</td>
<td>48.42731</td>
</tr>
<tr>
<td>TAD4.11</td>
<td>C. crossleyi</td>
<td>Mantadia</td>
<td>-18.80942</td>
<td>48.42731</td>
</tr>
<tr>
<td>TAD4.12</td>
<td>C. crossleyi</td>
<td>Mantadia</td>
<td>-18.80942</td>
<td>48.42731</td>
</tr>
<tr>
<td>TOR6.2</td>
<td>C. crossleyi</td>
<td>Torotorofotsy</td>
<td>-18.83658</td>
<td>48.34719</td>
</tr>
<tr>
<td>TORO8.11</td>
<td>C. crossleyi</td>
<td>Torotorofotsy</td>
<td>-18.77044</td>
<td>48.42814</td>
</tr>
<tr>
<td>TORO8.16</td>
<td>C. crossleyi</td>
<td>Torotorofotsy</td>
<td>-18.76856</td>
<td>48.42475</td>
</tr>
<tr>
<td>TVY7.12</td>
<td>C. crossleyi</td>
<td>Ambatovy</td>
<td>-18.85086</td>
<td>48.29256</td>
</tr>
<tr>
<td>TVY7.196B</td>
<td>C. crossleyi</td>
<td>Ambatovy</td>
<td>-18.86433</td>
<td>48.31136</td>
</tr>
<tr>
<td>TVY7.197</td>
<td>C. crossleyi</td>
<td>Ambatovy</td>
<td>-18.86658</td>
<td>48.30972</td>
</tr>
<tr>
<td>TVY7.199</td>
<td>C. crossleyi</td>
<td>Ambatovy</td>
<td>-18.87294</td>
<td>48.305</td>
</tr>
<tr>
<td>TVY7.20</td>
<td>C. crossleyi</td>
<td>Ambatovy</td>
<td>-18.84797</td>
<td>48.29433</td>
</tr>
<tr>
<td>TVY7.200</td>
<td>C. crossleyi</td>
<td>Ambatovy</td>
<td>-18.86883</td>
<td>48.30975</td>
</tr>
<tr>
<td>TVY7.206</td>
<td>C. crossleyi</td>
<td>Ambatovy</td>
<td>-18.87289</td>
<td>48.30453</td>
</tr>
<tr>
<td>TVY7.207</td>
<td>C. crossleyi</td>
<td>Ambatovy</td>
<td>-18.87178</td>
<td>48.30297</td>
</tr>
<tr>
<td>TVY7.22</td>
<td>C. crossleyi</td>
<td>Ambatovy</td>
<td>-18.85017</td>
<td>48.292</td>
</tr>
<tr>
<td>TVY7.33</td>
<td>C. crossleyi</td>
<td>Ambatovy</td>
<td>-18.85086</td>
<td>48.29256</td>
</tr>
<tr>
<td>ZAH240</td>
<td>C. crossleyi</td>
<td>Zahamena</td>
<td>-17.48917</td>
<td>48.74722</td>
</tr>
<tr>
<td>TRA8.81</td>
<td>C. sp. nov. 2</td>
<td>Andringitra (Ambarongy)</td>
<td>-22.22269</td>
<td>47.01889</td>
</tr>
<tr>
<td>TRA8.82</td>
<td>C. sp. nov. 2</td>
<td>Andringitra (Ambarongy)</td>
<td>-22.22292</td>
<td>47.0195</td>
</tr>
</tbody>
</table>

*Table continued on next page*
engaged in pastoral activities (predominantly cattle grazing) (Cornell University/USAID/FOFIFA/INSTAT Census 2001). Timber extraction, quarrying, and land clearance for cattle grazing are also threats to the endemic wildlife. These threats have been exacerbated by rapid population growth, low levels of education, and extreme poverty; factors that have led the human population to devastate the ecosystem to obtain needed resources (Gezon and Freed 1999; Marcus and Kull 1999; D’Cruze et al. 2008).

Genetic samples, measurements and photographs of several sedated *Cheirogaleus* individuals were taken prior to their release (Table 2). The samples taken from these animals were subsequently analyzed in the context of a larger phylogenetic study of the genus *Cheirogaleus* by Lei et al. (2014), and determined to be sufficiently distinct to warrant elevation as a new species in the *C. crossleyi* species group. The Montagne d’Ambre individuals were designated *Cheirogaleus* sp. nov. 1 by Lei et al. (2014), as were six other “confirmed candidate species” (CCS) that likely warrant elevation to full species status. Here we describe a new species of dwarf lemur endemic to the area around Montagne d’Ambre.

**Methods**

Methods used to identify this new species were presented in Lei et al. (2014). Briefly, extracted genomic DNA taken from safely immobilized animals was subjected to a series of wet bench and computational analyses (Table 2). The mitochondrial regions analyzed were: Cytochrome b (cytb) (Irwin et al. 1991); Cytochrome oxidase subunit II (COII); the displacement loop or control region (D-loop) (Baker et al. 1993; Wyner et al. 1999); a fragment of the Cytochrome oxidase subunit III gene (COIII); NADH-dehydrogenase sub units 3, 4L, and 4 (ND3, ND4L, and ND4); and the tRNA<sub>Gly</sub>, tRNA<sub>Arg</sub>, tRNA<sub>His</sub>, tRNA<sub>Ser</sub>, and partial tRNA<sub>Leu</sub> genes (PAST) (Pastorini et al. 2000). Three nuclear loci were also sequenced: alpha fibrinogen intron 4 (FIBA), von Willebrand Factor intron 11 (vWF), and Cystic Fibrosis Transmembrane conductance (CFTR-PAIRB) (Heckman et al. 2007; Horvath et al. 2008). All genetic data were then analyzed using Maximum Likelihood (ML) and Bayesian phylogenetic analyses, and subjected to a battery of tests to examine the strength of the results (Lei et al. 2014, Figs. 2–6, Appendix Ia–Id).

A Bayesian species delimitation analysis was performed using the bPTP webserver with 100,000 Markov Chain Monte Carlo generations, which is sufficient for datasets of less than 50 taxa (http://species.h-its.org; Zhang et al. 2013). The bPTP server uses a Bayesian Poisson tree processes model to add Bayesian support values to proposed species lineages on a
A New Species in the Genus *Cheirogaleus* (Cheirogaleidae)

user-supplied tree using the number of mutations in a lineage. The mitochondrial combined guide tree included representative populations from the total sample set of Lei et al. (2014), with all individuals sampled at Montagne d’Ambre (*Cheirogaleus* sp. nov. 1) and all other individuals in the *Cheirogaleus crossleyi* group (*C. crossleyi, CCS2, C. sp. nov. 2). Representatives from the other *Cheirogaleus* species groups (*C. lavasoensis, C. major, C. medius, C. sibreei*), as well as *Microcebus berthae* as an outgroup species, were also included in the bPTP analyses (Fig. 2).

Additionally, D-loop sequences were generated from fecal samples collected in February 2015 from Montagne d’Ambre (locations marked on Fig. 1), which were identical to those from blood and tissue samples. Because of the identical nature of these samples, they were not used in the analyses. The pelage of *Cheirogaleus* sp. nov. 1 was also compared to closely related species (Figs. 3 and 4).

**Results**

In the cyt b sequence fragment analyses, *Cheirogaleus* sp. nov. 1, differs from its closest genetic relatives in Lei et al. (2014) (CCS2, CCS3, *C. lavasoensis* and *C. crossleyi*) in genetic distance by 5.6%±0.7%, 6.3%±0.7%, 8.1%±0.8% and 6.2%±0.6%, respectively. Despite being relatively geographically close to CCS6, with the Irodo River as a barrier, *C. sp. nov. 1* is distinct from CCS6. The latter is clustered in the “Medius” subgroup clade with a genetic distance of 11.7%±0.9% between *C. sp. nov. 1* and CCS6. Additional analyses using the mitochondrial loci listed in the Methods section above resulted in *C. sp. nov. 1* segregating as an independent lineage with a high degree of confidence, but the results with nuclear loci were less robust among lineages even when large geographic distances (up to 900 km) were a factor. This may be the result of a number of factors, including incomplete lineage sorting, ancient introgression, or the small size of the nuclear sample analyzed (Lei et al. 2014, Fig. 5, Appendix Ib-Ic). The mitochondrial and nuclear phylogenetic trees generated in this study are available in Lei et al. (2014, Figs. 2-6, Appendix Ia-Ic).

The population aggregate analysis (PAA) results were congruent with those presented in Lei et al. (2014). We obtained a Bayesian PTP support value of 1.00 indicating an excellent probability of the likelihood that this lineage is an independent species based on the given mitochondrial dataset (Fig. 2).

**Discussion**

Sufficient mitochondrial genetic divergence was observed, in conjunction with differences in pelage, to warrant elevation of this population as a new species. Additional evidence used in elevating this population to species status was its geographic isolation from other populations of *Cheirogaleus*. *Cheirogaleus* sp. nov. 1 is found northwest of the Irodo River, and is isolated from other *Cheirogaleus* species by this boundary (Fig. 5). A similar geographical situation exists with the Montagne d’Ambre mouse lemur (*Microcebus arnholdi*) and the Tavaratra mouse lemur (*Microcebus tavaratra*), with the Irodo River acting as a barrier between the two lineages; pelage differences are visible between these two *Microcebus* species as well (Mittermeier et al. 2010). Geographic

![Figure 2. Results of the Bayesian species delimitation analyses of the combined mitochondrial dataset using the bPTP webserver (http://species.h-its.org). A total of 100,000 Markov Chain Monte Carlo generations were run with a rooted tree including the outgroup species *Microcebus berthae*. The Montagne d’Ambre population, site designation AMB (*Cheirogaleus* sp. nov. 1), had robust support (1.00) as an independent lineage within the *C. crossleyi* group.](https://bioone.org/journals/Primate-Conservation)
Figure 3. Illustrations of Cheirogaleus lineages based on archived photographs (Museum of Texas Tech University; Fig. 8 in Lei et al. 2014). Left panel represents all Cheirogaleus lineages, except C. sibreei. Right panel represents the Cheirogaleus crossleyi group, including Cheirogaleus sp. nov. 1, here named Cheirogaleus andysabini.

Table 2. List of dwarf lemurs, Cheirogaleus sp. nov. 1, from Montagne d’Ambre examined during this study using site designation acronyms for specimens, AMB and DAMB, collected by Omaha’s Henry Doorly Zoo and Aquarium (OHDZA) and Madagascar Biodiversity Partnership (MBP) field teams. Catalog and tissue accession numbers from the Museum of Texas Tech University (TTU-M).

<table>
<thead>
<tr>
<th>ID No.</th>
<th>Catalog No.</th>
<th>Tissue No.</th>
<th>Sex</th>
<th>Microchip ID</th>
<th>Weight (kg)</th>
<th>GPS</th>
<th>Sampling Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMB5.22</td>
<td></td>
<td></td>
<td>Male</td>
<td>466A1C1004</td>
<td>0.271</td>
<td>-12.52731</td>
<td>49.17331</td>
</tr>
<tr>
<td>AMB5.23</td>
<td></td>
<td></td>
<td>Male</td>
<td>463D653640</td>
<td>0.256</td>
<td>-12.53017</td>
<td>49.17464</td>
</tr>
<tr>
<td>AMB5.27</td>
<td>TTU-M 118801</td>
<td>TK 129239</td>
<td>Female</td>
<td>469753C7D</td>
<td>0.310</td>
<td>-12.51722</td>
<td>49.17950</td>
</tr>
<tr>
<td>AMB5.28</td>
<td>Female</td>
<td>466A1D6C48</td>
<td>0.391</td>
<td>-12.47881</td>
<td>49.21222</td>
<td>11/22/2005</td>
<td></td>
</tr>
<tr>
<td>AMB5.29</td>
<td>TTU-M 118802</td>
<td>TK 129240</td>
<td>Female</td>
<td>463B507D20</td>
<td>0.336</td>
<td>-12.47922</td>
<td>49.21606</td>
</tr>
<tr>
<td>AMB5.30</td>
<td>TTU-M 118803</td>
<td>TK 129241</td>
<td>Male</td>
<td>46714576F</td>
<td>0.296</td>
<td>-12.47917</td>
<td>49.21597</td>
</tr>
<tr>
<td>AMB5.31</td>
<td>Female</td>
<td>466A1D6C48</td>
<td>0.311</td>
<td>-12.51083</td>
<td>49.19275</td>
<td>11/22/2005</td>
<td></td>
</tr>
<tr>
<td>AMB5.32*</td>
<td>Male</td>
<td>465E502450</td>
<td>0.110</td>
<td>-12.51242</td>
<td>49.18956</td>
<td>11/23/2005</td>
<td></td>
</tr>
<tr>
<td>AMB5.34</td>
<td>Male</td>
<td>46C2017435</td>
<td>0.291</td>
<td>-12.47822</td>
<td>49.21717</td>
<td>11/22/2005</td>
<td></td>
</tr>
<tr>
<td>AMB5.35</td>
<td>Female</td>
<td>466C5E121D</td>
<td>0.321</td>
<td>-12.49519</td>
<td>49.20783</td>
<td>11/23/2005</td>
<td></td>
</tr>
<tr>
<td>DAMB15.4</td>
<td>Male</td>
<td>476F11225A</td>
<td>0.240</td>
<td>-12.52716</td>
<td>49.17191</td>
<td>02/28/2015</td>
<td></td>
</tr>
<tr>
<td>DAMB15.5</td>
<td>Female</td>
<td>47741F1E78</td>
<td>0.200</td>
<td>-12.52461</td>
<td>49.17236</td>
<td>02/28/2015</td>
<td></td>
</tr>
<tr>
<td>DAMB15.6</td>
<td>Male</td>
<td>4767432A7C</td>
<td>0.164</td>
<td>-12.52425</td>
<td>49.17302</td>
<td>02/28/2015</td>
<td></td>
</tr>
</tbody>
</table>

*Juvenile
A New Species in the Genus *Cheirogaleus* (Cheirogaleidae)

Figure 4. Illustration of *Cheirogaleus andysabini* and photographs of Omaha’s Henry Doorly Zoo and Aquarium (OHDZA) catalogue acronym for specimen DAMB15.4 taken at Montagne d’Ambre. Illustrations by Stephen D. Nash ©Conservation International. Photographs by Edward E. Louis, Jr.
Figure 5. Map of Madagascar with the ranges of Cheirogaleus sp. nov. 1 (Cheirogaleus andysabini) and closely related Cheirogaleus species highlighted to show the geographic distance between lineages. ID numbers on the map correspond to ID numbers of animals listed in Table 1. Photographs of Cheirogaleus sp. nov. 1 and CCS6 (Lei et al. 2014), the Ankaran/Andrafiamena/Analamera/Bekaraoka lineage is provided to show a clear difference in pelage and the distance between the ranges of the two lineages. The Irodo River acts as a northern barrier to CCS6.
isolation alone is not evidence for the elevation of a new species. However, when considered as one factor alongside mitochondrial genetic divergence and pelage variation it provides additional justification for the description of a new species. *Cheirogaleus* sp. nov. 1 has a deeper reddish-brown dorsal coat, and a white rather than grey ventral coat that distinguishes its pelage from that of the closely related *C. crossleyi* (Figs. 3, 4; See also Lei et al. 2014, Fig. 8). The average size of *C. sp. nov. 1* is generally smaller than *C. crossleyi* individuals, although there is overlap in body size among some individuals (Lei et al. 2014, Table 4).

The Bayesian species delimitation analysis provided posterior delimitation probabilities in support of our elevation of the Montagne d’Ambre *Cheirogaleus* group as an independent species. We acknowledge the limitations of any species delimitation methodology when used independent of other corroborating methods (Carstens et al. 2013). In the case of this *Cheirogaleus* group the bPTP species delimitation is presented as additional evidence of our assertion that this group constitutes a new species.

**Conservation Status**

Insufficient information is available about the conservation status of this species, but the rate of anthropogenic ecological destruction in this region of Madagascar (and Madagascar overall) is severe. The population of this new species is found in and just outside the boundaries of Montagne d’Ambre National Park. A region of unprotected forest remains between the northern boundary of the national park and the Forêt d’Ambre Special Reserve (Mittermeier et al. 2010). The conservation status of this species cannot be determined at present, but the proximity to the park boundary and the settlement of Joffreville brings this species into close contact with humans and the possibility of forest clearance and hunting. The large port city of Antsiranana (formerly Diego Suarez) is c. 30 km away, and the demand for cooking charcoal from the sizeable population there has led to increased stress on the forest ecosystem at Montagne d’Ambre. Furthermore, the clearing of forest for the production of khat (*Catha edulis*) in the past decade has increased dramatically (E.E. Louis, Jr. pers. obs.). Therefore, with combinations of threats such as hunting, deforestation, and subsistence farming, even lemur populations in parks and reserves are not necessarily protected (Dufils 2003; Schweitzer et al. 2014). Given the microendemism found in Montagne d’Ambre, it is imperative to safeguard this habitat for this newly described *Cheirogaleus* species and other rare wildlife confined to this unique and isolated rainforest.

**Cheirogaleus andysabini** sp. nov.

Formerly *Cheirogaleus* sp. nov. 1, also CCS1 (Lei et al. 2014).

Holotype: AMB5.27 (AMB is the Henry Doorly Zoo designation for Montagne d’Ambre); adult female; Permit number 181; 4 × 2.0 mm biopsies from ear pinna and 0.3 cc of whole blood; stored and curated at the Museum of Texas Tech University (MTTU, catalog number: TTU-M 118801/K 129239) Genetic Resources Collection, Natural Sciences Research Laboratory (NSRL); We placed a microchip subcutaneously between the scapulae and recorded as 4669753C7D; Collected by Jean Freddy Ranaivaroa, Ravaka Ramana-mahefa, Nirina Jean de Dieu Andramadison, Joseph Désiré Rabekinajna, Gérard Nalanirina, François Randrianasolo on 22 November 2005.

Paratypes: AMBS.25-5.32, 5.34-5.35, DAMB 15.4-15.6

Other specimens: Possible (unconfirmed), Harvard Museum of Comparative Zoology (MCZ) 44951, skull and skin from Montagne d’Ambre accessioned in January 1929 as part of the Grandidier Collection by Robert Barbour received from Louis Lavauden (missing in inventory since 1994). Additional specimen in the collection of the American Museum of Natural History (AMNH) M-100650, skull and skin taken in November of 1930 by Austin Rand at a site near Montagne d’Ambre “15 miles southwest of Tsarakimby.”

Type locality: Madagascar: Antsiranana Province, Diana Region, District Antsiranana II, Montagne d’Ambre National Park, S12.52720, E49.17950 at 1073 m above sea level.

Measurements of holotype: Measurements (in cm and g) recorded in a field catalog: Body length 18.2 cm; Tail length 27.1 cm; Head crown 5.8 cm; Mass 310 g.

Description: The dorsum, limbs, and head are a rufous brown. The areas around the orbits are brownish-black, with a white patch proximal to the fleshy part of the nose in the inter-ocular space. The pelage on the ventral surface of the mandible is white, which is continuous onto the white pelage of the ventrum. Size is generally smaller than *C. crossleyi*, braincase higher, with very poorly expressed temporal lines (Fig. 4).

Diagnosis: *Cheirogaleus andysabini* can be distinguished from *C. crossleyi*, CCS2, CCS3 and *C. lavasoensis* by 10, 7, 10 and 16 amorphous characters in the cytochrome b gene, respectively (Appendix II(k); Lei et al. 2014). *Cheirogaleus andysabini* has four diagnostic sites in the cytb sequence fragment such as G, A, G and G at the positions of 297, 303, 306 and 1071, respectively, which differentiate *C. andysabini* from all other *Cheirogaleus* species. Despite being geographically close to CCS6, with the Irodo River as a barrier, *C. andysabini* is distinct by nine diagnostic characters from CCS6, which is clustered in the “Medius” subgroup clade. An average weight of 0.282 ±0.61 kg, dark fur around eyes, rufous brown fur on dorsum, limbs, and head, venter is white. Table 3 contains measurements of captured individuals.

Distribution: *Cheirogaleus andysabini* is known from the Montagne d’Ambre National Park and areas nearby around the town of Joffreville, northwest of the Irodo River in northern Madagascar (Fig. 1). Observed at 541–1073 m above sea level.

Etymology: This new species is named after Andy Sabin, a well-known New York philanthropist committed to species conservation, especially turtles, amphibians and primates. In particular, he has supported many projects in Madagascar,
including research on lemurs, tortoises and frogs. His long-term interest, his enthusiasm, and his generosity have helped to encourage many researchers and conservationists, young and old alike.

Vernacular names: Montagne d’Ambre or Andy Sabin’s dwarf lemur.

Acknowledgments

We thank the Madagascar National Parks and Ministere de l’Environnement et de Forêts for sampling permission. We are most grateful to The Ahmanson Foundation, the Theodore F. and Claire M. Hubbard Family Foundation, the Primate Action Fund / Conservation International, the Margot Marsh Biodiversity Foundation, and the National Geographic Society, for financial assistance. Colin Groves thanks Eileen Westwig, Judy Chupasko, Larry Heaney, Paula Jenkins, Chris Smeenk, Frieder Meier, and Cecile Callou for access to museum specimens under their care. In particular, thanks go to the Harvard Museum of Comparative Zoology and the American Museum of Natural History for photographs from their collection. We also want to acknowledge the office and field staffs of the Madagascar Biodiversity Partnership for their excellence in collecting the samples from the Cheirogaleus safely, and returning them to their forest habitat. We are most grateful to two reviewers for their insights and helpful suggestions.

Literature Cited


A New Species in the Genus Cheirogaleus (Cheirogaleidae)
Lei et al.


Authors’ addresses:

**Runhua Lei**, **Adam T. McLain**, **Cynthia L. Frasier**, **Justin M. Taylor**, **Carolyn A. Bailey**, **Shannon E. Engberg**, **Azure L. Ginter**, Grewcock Center for Conservation and Research, Omaha’s Henry Doorly Zoo and Aquarium, 3701 South 10th Street, Omaha, NE 68107-2200, USA, **Stephen D. Nash**, Department of Anatomical Sciences, School of Medicine, Stony Brook University, Stony Brook, NY 11794-8081, USA, **Richard Randriamampionona**, Madagascar Biodiversity Partnership, Manakambahiny, Antananarivo, Madagascar, **Colin P. Groves**, School of Archaeology and Anthropology, Faculty of Arts, Australian National University, Canberra, ACT 0200, Australia, **Russell A. Mittermeier**, Conservation International, 2011 Crystal Drive, Arlington, VA 22202, USA, and **Edward E. Louis, Jr.**, Grewcock Center for Conservation and Research, Omaha’s Henry Doorly Zoo and Aquarium, 3701 South 10th Street, Omaha, NE 68107-2200, USA. Corresponding author: Edward E. Louis, Jr. <edlo@omahazo.com>, <genetics@omahazo.com>.

Received for publication: 20 May 2015
Revised: 8 July 2015
Posted on the internet: 26 August 2015
Published: 15 December 2015