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Sylvain Randrianjaka

Samantha Calkins

Timothy M. Sefczek

Cynthia L. Frasier

Richard Randriamampionona

See next page for additional authors

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Authors

Sylvain Randrianjaka, Samantha Calkins, Timothy M. Sefczek, Cynthia L. Frasier, Richard Randriamampionona, Jean Claude Rakotoniaina, Lily-Arison R. de Roland, Andrea L. Baden, and Edward E. Louis Jr.

Assessment of ring-tailed lemur *Lemur catta* populations in south-western Madagascar

SYLVAIN RANDRIANJAKA, SAMANTHA CALKINS, TIMOTHY M. SEFCZEK
CYNTHIA L. FRASIER, RICHARD RANDRIAMAMPIONONA
JEAN CLAUDE RAKOTONIAINA, LILY-ARISON R. DE ROLAND
ANDREA L. BADEN and EDWARD E. LOUIS JR

Abstract Anthropogenic activities are negatively affecting the flora and fauna of Madagascar, including its Endangered flagship lemur species, the ring-tailed lemur *Lemur catta*. Population numbers at some sites are rapidly declining, yet much of the species' habitat is insufficiently surveyed. Because widespread population assessments are critical to guiding conservation management strategies, additional data are needed to monitor *L. catta* population trends and to identify the limits of their geographical range. Here we report survey results confirming the presence of this species at 65 of 83 sites in southern and south-western Madagascar, including three subpopulations that were previously considered likely to be locally extinct. We identified a minimum of 792 *L. catta* individuals (summing only maximum group sizes at each site) and as many as 1,221 individuals (using estimated population counts). These findings help refine the distribution of *L. catta* and reaffirm their presence in areas of their historical geographical range. Identifying species occupancy at sites such as these provides valuable data

to support species conservation, but also highlights the need for additional surveys throughout the range of the species.

Keywords Broad survey methods, conservation, *Lemur catta*, line transect surveys, Madagascar, population counts, ring-tailed lemur, species distribution

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According to the IUCN Red List, c. 94% of the > 100 lemur species of Madagascar are threatened, making them the most endangered mammalian group globally (Schwitzer et al., 2014). The Endangered ring-tailed lemur *Lemur catta*, a flagship species for the country, is believed to be suffering precipitous population declines (Gould & Sauther, 2016; LaFleur et al., 2018; LaFleur & Gould, 2020). Once considered widespread throughout southern Madagascar (Sussman, 1977), *L. catta* is now considered locally extinct or nearly extinct at several locations where it was found historically (Gould & Sauther, 2016; LaFleur et al., 2016, 2018; LaFleur & Gould, 2020; Fig. 1). Nevertheless, much of the historical range of the species remains under-surveyed, raising concerns that current population estimates potentially under-represent *L. catta* numbers in the wild (Murphy et al., 2017).

Accurate population assessments are essential for informing species-orientated conservation management (Rylands et al., 2020), including that of *L. catta* (LaFleur & Gould, 2020). To aid these efforts, we present survey results from 83 sites to verify the species' occurrence, refine knowledge of its distribution and contribute to population estimates (Fig. 1).

During June–July 2019 we conducted surveys at five sites where *L. catta* occurred historically that were either excluded from recent population estimates or had not been systematically surveyed since 1995 (Hawkins, 1999): (1) Zombitse Forest, (2) Vohibasia Forest, (3) Fiherenana Forest, (4) Ranomay Forest, and (5) two trail circuits in Isalo National Park (Namaza Circuit and Piscine Naturelle) (Fig. 1). We conducted week-long surveys using a standard line transect methodology along existing trails, to minimize forest disturbance (Whitesides et al., 1988; Hilário et al., 2012; see Supplementary Material 1 for full details).

During 2-week periods in June, August, September and October 2018 and March, April and August 2019, we surveyed a further 78 sites across seven *fokontany* (an administrative

SYLVAIN RANDRIANJAKA* École Doctorale de Biodiversité et Environnement Tropical, Université de Toliara, Toliara, Madagascar

SAMANTHA CALKINS* Animal Behavior and Conservation Program, Department of Psychology, Hunter College of the City University of New York, New York, USA

TIMOTHY M. SEFCZEK‡ (Corresponding author, orcid.org/0000-0003-3612-3216, tsefczek2@unl.edu) University of Nebraska, 1400 R Street, Lincoln, NE 68588, USA

CYNTHIA L. FRASIER († orcid.org/0000-0002-5416-2000) Omaha's Henry Doorly Zoo and Aquarium, Omaha, Nebraska, USA

RICHARD RANDRIAMAMPIONONA and JEAN CLAUDE RAKOTONIAINA Madagascar Biodiversity Partnership, Antananarivo, Madagascar

LILY-ARISON R. DE ROLAND († orcid.org/0000-0003-2149-8170) The Peregrine Fund's Madagascar Project, Antananarivo, Madagascar

ANDREA L. BADEN†§¶ (Corresponding author, orcid.org/0000-0002-4722-0532, andrea.baden@hunter.cuny.edu) Department of Anthropology, Hunter College of the City University of New York, New York, USA

EDWARD E. LOUIS JR†‡ († orcid.org/0000-0002-3634-4943) Madagascar Biodiversity Partnership, Antananarivo, Madagascar

*Co-first authors

†Co-last authors

‡Also at: Omaha's Henry Doorly Zoo and Aquarium, Omaha, USA

§Also at: Department of Anthropology, The Graduate Center of the City University of New York, New York, USA

¶Also at: The New York Consortium in Evolutionary Primatology, New York, USA

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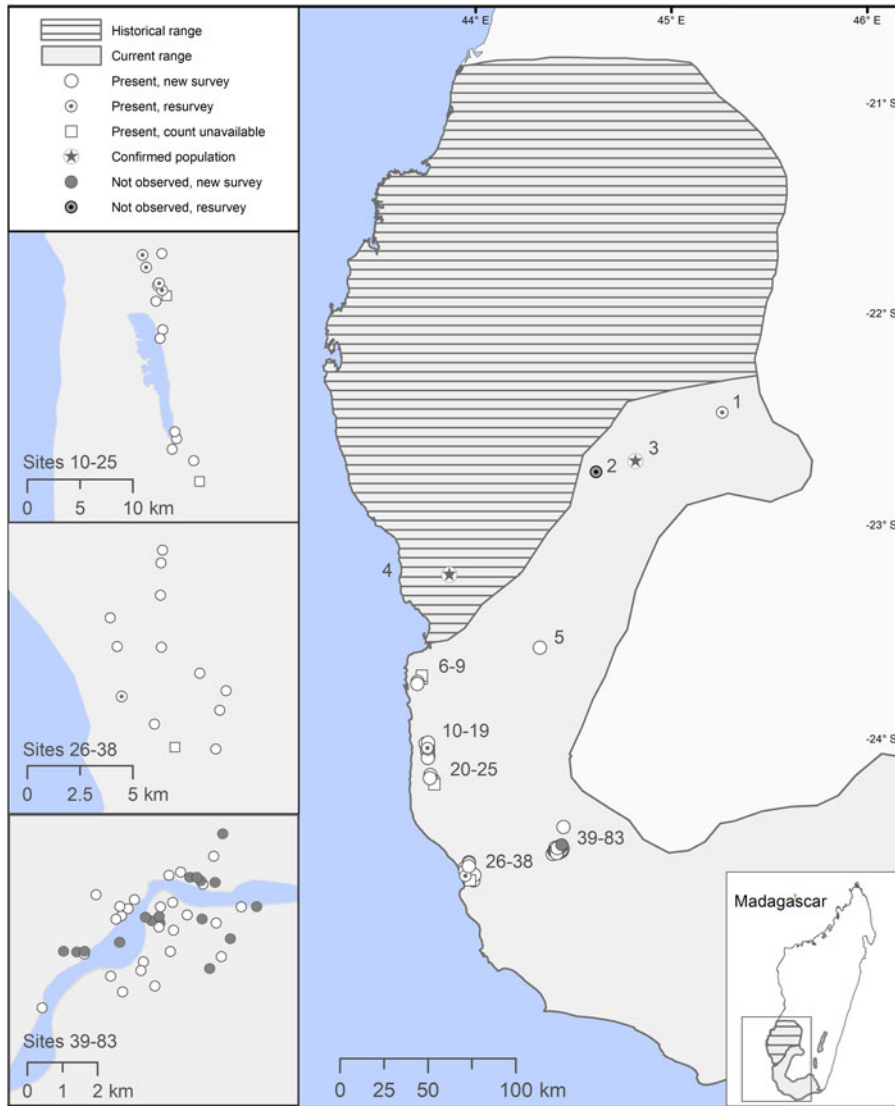


FIG. 1 Locations of the 83 surveys for the ring-tailed lemur *Lemur catta* conducted during June 2018–August 2019 in southern Madagascar. Supplementary Table 1 contains the corresponding site names and numbers. Extant and historical *L. catta* distributions are from the IUCN Red List (LaFleur & Gould, 2020). ‘New survey’ refers to data from this study for sites for which there are no other published surveys. ‘Resurvey’ indicates sites for which other published surveys are also available (Supplementary Table 1). ‘Confirmed population’ indicates sites where species presence has been confirmed despite being previously identified as likely locally extinct (Gould & Sauther, 2016; LaFleur et al., 2016).

unit comprising one or more villages) throughout the Mahafaly Plateau, a vast region of south-western Madagascar where surveys for this species have been insufficient (LaFleur et al., 2016; Fig. 1). The sites surveyed around the Mahafaly Plateau lack the infrastructure for conducting line transect sampling; we therefore used broad survey methods following Sussman et al. (2003) to count individuals at sleeping sites (see Supplementary Material 1 for full details). We utilized broad survey methods because of their ability to generate comparative datasets at low cost over relatively short periods of time and their utility for confirming the presence and relative numbers of the population of a species within a proscribed area (Muckenhirn et al., 1975).

The combined results from our surveys confirm the presence of *L. catta* at 65 (78.3%) of the 83 sites. We identified a minimum of 792 *L. catta* individuals in total (summing only the maximum group size across sites; Supplementary Table 1) and as many as 1,221 individuals (using estimated population counts) from 104 groups at 60 sites (Supplementary Table 1). Our estimates at four sites in the Mahafaly

Plateau (Vintany, Andranoilovy, Grotte Maiky and Andranovao South) corroborate the findings presented in a recent report (Kasola et al., 2020). Furthermore, we confirmed the presence of *L. catta* at a further five sites on the Mahafaly Plateau (Antsono, Ankamena, Andramaniloke, Marohazo and Vohindambo), although individuals were obscured from view, making accurate counts impossible. Local guides indicated *L. catta* was present at the remaining 18 sites, although our surveys did not confirm this.

Among our surveys were three sites where *L. catta* populations were believed previously to be locally extinct or nearly extinct: Zombitse, Vohibasias and Fiheranana (Supplementary Table 1). As in a previous study (La Fleur et al., 2016), we did not detect *L. catta* in Zombitse Forest, but we did confirm presence at both Vohibasias and Fiheranana forests. At Vohibasias, which was last surveyed in 2007 (Siers, 2007), we observed 10 individuals, thus indicating species persistence in this region, albeit at low densities. We observed a total of 40 individuals in five groups at Fiheranana; local guides suggest that additional *L. catta*

populations occur along the Fiheranana River Valley where it extends beyond the range of our survey. Our survey efforts also confirmed that Ranomay, a historical *L. catta* stronghold (Murphy et al., 2017), and multiple sites throughout the Mahafaly Plateau (e.g. Bemananga, Mananiho and Telomaly) still support a substantial presence of *L. catta* (Supplementary Table 1).

Although encouraging, our findings are preliminary; additional systematic surveys are needed to improve population estimates of *L. catta*. Nevertheless, our data are important for informing species-orientated conservation management (Kéry & Schmidt, 2008). Our findings are also a cautionary reminder that we must not confuse data deficiency with population deficiency; both survey extent and habitat heterogeneity (i.e. the 'geographical template' sensu Lomolino, 2004) must be considered when inferring species occupancy, as the absence of a species from one area might not be indicative of its absence from an entire region (Angermeier et al., 2002). Thus, it is important that additional surveys are conducted beyond the regions included in this study. Failure to do so could lead to so-called Wallacean shortfalls (i.e. gaps in understanding of the geographical distribution of a species; Lomolino, 2004). We therefore echo a recent call (LaFleur et al., 2018) for widespread collaboration between researchers, conservationists and park management officials to generate more comprehensive information on the density and distribution of *L. catta* throughout its geographical range, to inform management of the species appropriately.

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Author contributions Study design, fieldwork: SR, SC, TMS, CLF, RR, JCR, ALB, EEL; data analysis, writing: SR, SC, TMS, ALB; revision: CLF, LRR, EEL.

Conflicts of interest None.

Ethical standards This research abided by the *Oryx* guidelines on ethical standards. The research was conducted with permission from Madagascar's Ministère de l'Environnement et du Développement Durable (126/18/MEEF/SG/DGF/DSAP/SCB.Re, 063/19/MEDD/SG/DGF/DSAP/SCB.Re and 324/19/MEDD/SG/DGEF/DGRNE), and was approved by institutional animal care and use committees on 12 June

2019 (Hunter College: AB-Wild Pet 4/22) and 18 January 2019 (Omaha's Henry Doorly Zoo and Aquarium: 190001).

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