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# A Habitat Stronghold on the Precipice: A call-to-action for supporting lemur conservation in northeast Madagascar

Timothy M. Eppley  
*Portland State University*

Cortni Borgerson  
*Montclair State University*

Natalie Vasey  
*Portland State University, nvasey@pdx.edu*

multiple additional authors

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## COMMENTARY

# A habitat stronghold on the precipice: A call-to-action for supporting lemur conservation in northeast Madagascar

Timothy M. Eppley<sup>1,2</sup>  | Cortni Borgerson<sup>3,4</sup>  | Erik R. Patel<sup>5</sup> |  
James P. Herrera<sup>6</sup>  | Andrew E. Kirkby<sup>7</sup> | Christopher D. Golden<sup>4,8</sup>  |  
McAntonin Andriamahaiavana<sup>9</sup> | Lanto Andrianandrasana<sup>6</sup> | Antonio Bóveda<sup>10</sup> |  
Dean Gibson<sup>1</sup> | Louis Joxe Jaofeno<sup>5</sup> | Fenohera Rakotondrasoa<sup>11</sup> |  
Tiana A. Ramahaleo<sup>11</sup> | Delaïd C. Rasamisoa<sup>1</sup> | Felix Ratelolahy<sup>10</sup> |  
Josia Razafindramanana<sup>12</sup> | Charlotte Spira<sup>10</sup>  | Charles Welch<sup>6</sup> | Natalie Vasey<sup>2</sup> 

<sup>1</sup>Conservation Science and Wildlife Health, San Diego Zoo Wildlife Alliance, Escondido, California, USA

<sup>2</sup>Department of Anthropology, Portland State University, Portland, Oregon, USA

<sup>3</sup>Department of Anthropology, Montclair State University, Montclair, New Jersey, USA

<sup>4</sup>Madagascar Health and Environmental Research (MAHERY), Maroantsetra, Madagascar

<sup>5</sup>Lemur Conservation Foundation, Myakka City, Florida, USA

<sup>6</sup>Duke Lemur Center SAVA Conservation, Duke University, Durham, North Carolina, USA

<sup>7</sup>Birdlife International, Conservation Department, Cambridge, UK

<sup>8</sup>Department of Nutrition, Harvard T. H. Chan School of Public Health, Boston, Massachusetts, USA

<sup>9</sup>Mention Zoologie et Biodiversité Animale, Faculté des Sciences, Université d'Antananarivo, Antananarivo, Madagascar

<sup>10</sup>Wildlife Conservation Society, Madagascar Program, Antananarivo, Madagascar

<sup>11</sup>WWF Madagascar Country office, Antananarivo, Madagascar

<sup>12</sup>Mention Anthropobiologie et Développement Durable, Faculté des Sciences, Université d'Antananarivo, Antananarivo, Madagascar

## Correspondence

Timothy M. Eppley, Conservation Science & Wildlife Health, San Diego Zoo Wildlife Alliance, Escondido, California, USA.  
Email: [eppleyti@gmail.com](mailto:eppleyti@gmail.com)

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## Abstract

The northeast of Madagascar is as diverse as it is threatened. The area bordering the Analanjirofo and SAVA regions contains six protected areas and at least 22 lemur species. Many applied research and conservation programs have been established in the region with the aim of ensuring both wildlife and people thrive in the long term. While most of the remaining humid evergreen forest of northeast Madagascar is formally protected, the local human population depends heavily on the land, and

**Abbreviations:** CAPAM, Ambohimirahavy Marivorahona Protected Area Complex; CIRAD, Center de Cooperation Internationale en Recherche Agronomique pour le Développement (French Agricultural Research Center for International Development); CITES, Convention on International Trade in Endangered Species of Wild Fauna and Flora; COBA(s), *Communautés de Base* (community forest associations); COMATSA-Sud, Corridor Marojejy-Anjanaharibe Sud-Tsaratanana; CR, Critically Endangered; CURSA, Center Universitaire Région de la SAVA; DLC, Duke Lemur Center; EN, Endangered; GIS, Geographic Information System; GPS, Global Positioning System; IMVAVET, Malagasy Institute for Veterinary Vaccines; IUCN SSC, International Union for Conservation of Nature Species Survival Commission; LCF, Lemur Conservation Foundation; MAHERY, Madagascar Health and Environmental Research; NGO, Nongovernmental Organization; NT, Near Threatened; PHE, Population-Health-Environment; PSU, Portland State University; SAVA, Region in northeast Madagascar; SDZWA, San Diego Zoo Wildlife Alliance; SMART, Spatial Monitoring and Reporting Tool; UA, University of Antananarivo; VOI, *Vondron'Olona Ifotony* (community forest protection associations); VU, Vulnerable; WCS, Wildlife Conservation Society; WWF, World Wide Fund for Nature.

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unsustainable natural resource use threatens this biodiversity hotspot. Drawing from our collective experiences managing conservation activities and research programs in northeast Madagascar, we discuss the major threats to the region and advocate for eight conservation activities that help reduce threats and protect the environment, providing specific examples from our own programs. These include (1) empowering local conservation actors, (2) ensuring effectively protected habitat, (3) expanding reforestation, (4) establishing and continuing long-term research and monitoring, (5) reducing food insecurity, (6) supporting environmental education, (7) promoting sustainable livelihoods, and (8) expanding community health initiatives. Lastly, we provide a list of actions that individuals can take to join us in supporting and promoting lemur conservation.

#### KEYWORDS

biodiversity monitoring, community health, environmental education, reforestation, sustainable livelihoods

## 1 | INTRODUCTION

From high-altitude forests with striking peaks to beautiful sandy beaches lined by lush rainforest along a picturesque coast, northeast Madagascar is by most accounts a tropical paradise. The northeast is also one of the highest priority areas for conservation in Madagascar due to its high species diversity and the increasing threats to its flora and fauna (Borgerson, Johnson, et al., 2022; Herrera, 2017; Vasey & Godfrey, 2022; Zaehring et al., 2015). The applied research and conservation projects discussed in this commentary are seated within the SAVA and Analanjirofo regions, spanning the towns of Sambava in the north to Mananara farther south (Figure 1). These regions contain the largest humid evergreen forest blocks remaining in Madagascar (Goodman et al., 2018). Included are Masoala National Park (2300 km<sup>2</sup>) and Makira Natural Park (3850 km<sup>2</sup>), both among the larger protected areas in Madagascar. The northeast also includes Anjanaharibe-Sud Special Reserve (374.8 km<sup>2</sup>), Marojejy National Park (555 km<sup>2</sup>), the COMATSA-Sud that unites the latter two areas, (Corridor Marojejy-Anjanaharibe Sud-Tsaratanana, 826.5 km<sup>2</sup>, formerly known as the Betaolana corridor), and Nosy Mangabe National Park (90.5 km<sup>2</sup>), an island in Antongil Bay. The mountainous rainforests of Marojejy National Park and Anjanaharibe-Sud Special Reserve were established as protected areas in 1952 and 1958, respectively, and are among the least disturbed ecosystems in this area. Masoala National Park, renowned for rare littoral and lowland rainforest, and Marojejy National Park form part of the Atsinanana World Heritage Site, so designated due to their exceptional biodiversity. COMATSA-Sud and Makira are the most recently established protected areas (2015 and 2012, respectively), and due to its central location, the forests of Makira are vital in maintaining long-term connectivity between the protected areas of this region.

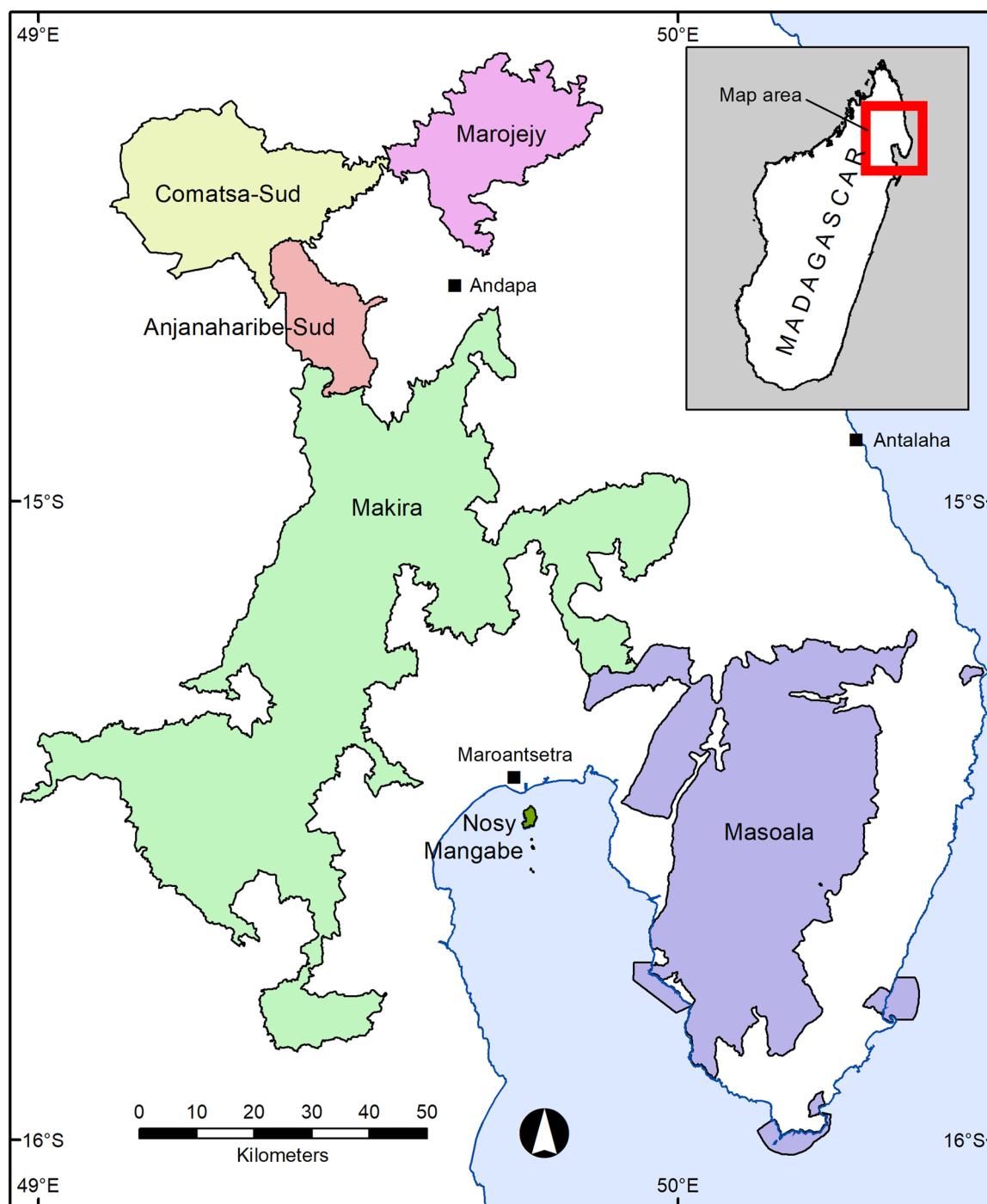
Together these areas harbor at least 22 recognized lemur species in northeastern Madagascar (IUCN, 2022; Mittermeier et al., 2023;

see Table 1). Of these, six species are listed as Critically Endangered (CR), seven are Endangered (EN), eight are Vulnerable (VU), and one is listed as Near Threatened (NT). One species, *Microcebus jonahi*, was recently discovered (Schüßler, Blanco, et al., 2020), and it is very likely that other still-undescribed and threatened species are hidden in these forests.

## 2 | MAJOR THREATS

Nationally, with only 5.2% of arable land remaining, the 29 million Malagasy residents face increasingly limited options as the human population is predicted to reach 54 million by 2050 (United Nations, 2022). Residents in northeast Madagascar depend heavily on the region's rivers, reefs, seas, forests, and agricultural lands, much of which is now within Madagascar's protected area network (Llopis et al., 2021). Farmers typically grow rice in irrigated lowlands or use traditional shifting agriculture on hillsides in and around protected areas to grow rain-fed rice, tubers, and vegetables (Herrera et al., 2021). Because of low food security, high malnutrition, and insufficient alternatives to animal-based foods, rural communities hunt many species of wildlife, including endemic lemurs, tenrecs, bats, carnivorans, and birds (Borgerson et al., 2019; Brook et al., 2019; Golden et al., 2019; Randriamady et al., 2021; Spira et al., 2021). Bushmeat hunting is exacerbated by poor enforcement of existing hunting and firearm laws, insufficient forest patrols, as well as an erosion of historical hunting taboos (Jenkins et al., 2011). Minimal forest monitoring and incomplete park boundary demarcation have exacerbated these drivers of endemic wildlife depletion (Patel, 2021).

These factors, in addition to poverty, corruption, and unstable (often extreme) weather events (e.g., droughts, cyclones) have led to increased deforestation for both subsistence (e.g., rice) and cash (e.g., vanilla) crops (Llopis et al., 2020; Martin et al., 2020;



**FIGURE 1** Protected areas of northeast Madagascar.

Schüßler, Mantilla-Contreras, et al., 2020; Zaehring et al., 2017). While cash crops can provide a pathway out of poverty, market prices can be volatile and lead to food insecurity, crime, and habitat disturbance inside protected areas, such as the sharp rise in illegal vanilla plantations in Marojejy in recent years.

Many species of hardwood have long supplied the region with timber for housing and furniture (Patel, 2007, 2010). These tree species are also used by CR lemurs; red ruffed lemurs consume resources from, and stash infants in, several species of rosewood (*Dalbergia* spp.) and ebony

(*Diospyros* spp.; Vasey et al., 2018), and silky sifakas feed on leaves of both species and use *Dalbergia* as sleeping trees (Mills et al., 2021). The presidential political crisis in 2009 led to an unprecedented increase in illegal logging of rosewood and ebony, primarily in the northeastern national parks. Over 52,000 tons (approximately 100,000 trees) of rosewood and ebony trees were exported in 2009 alone, more than double the amount exported in 2008 (Randriamalala & Liu, 2010). This intensive selective logging continued for several years, finally subsiding once the newly elected president took power in early 2014. However,

**TABLE 1** Lemur species inhabiting northeast Madagascar.

Family	Common name	Scientific name	IUCN Red List status (2020)	Protected areas
<b>Lemuridae</b>				
	Red ruffed lemur	<i>Varecia rubra</i>	CR A4cd	MAK, MAS
	White-belted ruffed lemur	<i>Varecia variegata</i> ssp. <i>subcincta</i>	CR A2cd + 3cd + 4cd	MAK, NM
	White-fronted brown lemur	<i>Eulemur albifrons</i>	VU A2cd	AS, CS, MAK, MAR, MAS, NM
	Red-bellied lemur	<i>Eulemur rubriventer</i>	VU A2cd + 4cd	AS, CS, MAK, MAR
	Common brown lemur	<i>Eulemur fulvus</i>	VU A4cd	MAK
	Northern bamboo lemur	<i>Haplemur occidentalis</i>	VU A2cd	AS, CS, MAK, MAR, MAS
<b>Indriidae</b>				
	Silky sifaka	<i>Propithecus candidus</i>	CR C2a(i)	AS, CS, MAK, MAR
	Indri	<i>Indri indri</i>	CR A3cd + 4cd	AS, MAK, CS
	Moore's woolly lemur	<i>Avahi mooreorum</i>	EN B1ab(i,iii,v)	MAS
	Eastern woolly lemur	<i>Avahi laniger</i>	VU A3cd	AS, CS, MAK, MAR
<b>Lepilemuridae</b>				
	Scott's sportive lemur	<i>Lepilemur scottorum</i>	EN B1ab(i,iii,v)	MAS
	Seal's sportive lemur	<i>Lepilemur seali</i>	VU A2cd + 3cd + 4cd; B1ab(i,iii,iv,v)	AS, CS, MAK, MAR
	Holland's sportive lemur	<i>Lepilemur hollandorum</i>	CR A2cd + 3cd + 4cd	MAK <sup>a</sup>
<b>Cheirogaleidae</b>				
	Hairy-eared dwarf lemur	<i>Allocebus trichotis</i>	EN A3cd + 4cd	AS, CS, MAK, MAR, MAS
	Greater dwarf lemur	<i>Cheirogaleus major</i>	VU A4cd	AS, CS, MAK, MAR, MAS
	Crossley's dwarf lemur	<i>Cheirogaleus crossleyi</i>	VU A4cd	AS, CS, MAK, MAR
	Sibree's dwarf lemur	<i>Cheirogaleus sibreei</i>	CR A4c	CS, MAR
	Anjahely mouse lemur	<i>Microcebus macarthurii</i>	EN B1ab(i,iii)	MAK
	Goodman's mouse lemur	<i>Microcebus lehilahytsara</i>	NT A2cd + 3cd + 4cd	AS, CS, MAK, MAR
	Jonah's mouse lemur	<i>Microcebus jonahi</i>	EN B1ab(ii,iii,iv,v)	MAK <sup>a</sup>
		<i>Microcebus</i> sp.		MAS
		<i>Microcebus</i> sp.		NM
	Masoala fork-marked lemur	<i>Phaner furcifer</i>	EN A2acd + 3cd + 4acd	MAK, MAS
<b>Daubentonidae</b>				
	Aye-aye	<i>Daubentonia madagascariensis</i>	EN A2cd + 3cd + 4cd	AS, CS, MAK, MAR, MAS, NM

Abbreviations: AS, Anjanaharibe-Sud Special Reserve; CS, Comatsa-Sud; MAK, Makira Natural Park; MAR, Marojejy National Park; MAS, Masoala National Park; NM, Nosy Mangabe National Park.

<sup>a</sup>Presumed occurrence.

illegal exports of concealed and stockpiled logs continued. In 2014, nearly 40,000 rosewood logs originating from Madagascar were confiscated in the ports of Singapore, Kenya, and Sri Lanka; one of the largest seizures of illegally harvested CITES species ever recorded. Approximately 30,000 rosewood and ebony logs currently remain in stockpiles in Madagascar (Roberts et al., 2022).

More recently, the Covid-19 pandemic brought tourism to a halt in late March 2020. The ensuing economic crisis caused by lockdowns has seemingly accelerated many of these previous

problems to the extent that many communities living adjacent to the region's protected areas are now increasingly dependent on local natural resources. As an example, the decrease or cessation of management activities within protected areas has led to a steep increase in human-set forest fires, with 76%–248% more monthly fires after lockdown in March to July 2020 than in 2012–2019 (Eklund et al., 2022).

Lastly, the paving of the 150 km road from Ambilobe to Vohemar, which was previously considered one of the world's least

accessible regions (Rice et al., 2021), is scheduled for completion in 2023 (financed by the controversial Belt & Road Initiative; BRI, 2021) and is expected to bring local economic benefits to the SAVA region. However, it also has the potential to increase the unsustainable exploitation of natural resources and accelerate biodiversity loss, changes likely to have a significant effect on the region's threatened primate species (Ascensão et al., 2022). The region's subsistence and cash economies depend heavily on the land, as do many current development strategies (e.g., cash crops). As population, economy, and connectivity grow, and the commercial value of land increases, conservation efforts will need to keep pace with such economic pressures to deliver benefits which either rival or mitigate the benefits of converting forests to agricultural landscapes.

### 3 | CONSERVATION GOALS AND ACTIONS FOR NORTHEAST MADAGASCAR

Several high-impact publications provide clear conservation actions for Madagascar. The Lemur Action Plan, a report by the IUCN SSC Primate Specialist Group (Schwitzer et al., 2013), recommends three major approaches to save lemurs in the wild: promoting eco-tourism, supporting community-managed protected areas, and expanding long-term research (Schwitzer et al., 2014). The CITES Madagascar Rosewood Action Plan, established after all Malagasy rosewood and ebony were uplisted to CITES Appendix II, suggests several actions including science-based export quotas, development of techniques to identify specific species, embargo on stockpile exports pending stockpile audits, and implementation of timber tracking technology (Mason et al., 2016). More recently, Jones et al. (2019) advocate that Madagascar's President, Andry Rajoelina, undertake five actions that would benefit people and nature: (1) tackle environmental crime, (2) invest in protected areas, (3) ensure infrastructure developments limit impacts on biodiversity, (4) strengthen local tenure rights over natural resources, and (5) address the growing fuelwood crisis. Finally, the president of Madagascar recently launched the "Family Planning 2030 initiative" (UNFPA, 2021) which aims to support family planning and ensure access to contraception. Population-Health-Environment (PHE) programs recognize that population growth is one of the primary drivers of biodiversity loss (Harris et al., 2012). Environmental organizations are increasingly jointly working with local communities to support women's health and family planning as an integral collaborative part of community-based natural resource management.

Northeast Madagascar has its own set of conservation challenges given its relative inaccessibility, and the fact that its large size and high border-to-interior ratios of its protected areas co-exist with a largely forest-dependent, poor, and malnourished human population. To ensure the conservation of forest habitats and their fauna, including lemurs, it is imperative to support local human populations while maintaining the integrity of protected area borders. We advocate for conservation activities with a focus on eight main areas: (1) empowering and partnering with local conservation actors,

(2) ensuring native habitat is effectively protected, both within established protected areas and in community-managed forests, (3) expanding reforestation efforts, (4) establishing and continuing long-term biological research and ecological monitoring, including lemur population monitoring, (5) reducing food insecurity through improved, diversified practices that include infrastructure improvement, alternative protein initiatives, and agroecological techniques, (6) supporting environmental education, (7) promoting sustainable livelihood opportunities that are either nature-positive or that do not rely on extractive use, and (8) expanding community health initiatives including PHE programs.

#### (1) Empower local conservation actors

By supporting and partnering with local educational and conservation organizations, we promote a place-based approach with significant and early investment from local stakeholders. Northeast Madagascar's sole undergraduate university, Center Universitaire Région de la SAVA (CURSA), trains students in sustainable natural resource management and agronomy, preparing the next generation of scientists to work for the national park service and local government ministries, or to become teachers and agro-entrepreneurs. By supporting CURSA's efforts to provide high-quality education for local students, these students will have better opportunities to positively impact their communities. In partnership with CURSA, the Duke Lemur Center (DLC) and other organizations have created training and support opportunities for students and faculty. For example, since 2019, the DLC and CURSA have co-hosted annual workshops on scientific methods: field workshops on ecological methods in Marojejy National Park, and workshops on research design, statistics, and natural history collections. DLC also supports undergraduate and graduate research by providing fellowships, competitive small grants, and internships in agroecology, reforestation, and fish farming. The Lemur Conservation Foundation (LCF) recently trained CURSA students on methods of long-term monitoring of silky sifakas (*Propithecus candidus*), including the use of handheld GPS units, and hosted a week-long GIS training program in September 2022 with more than a dozen participants from local organizations.

The World Wide Fund for Nature (WWF) supports the largest community-managed forestry program in the region. Since 2015, the WWF manages COMATSA (Nord and Sud, 318,000 ha) which is part of the Ambohimirahavavy Marivorahona Protected Area Complex (CAPAM), a network of five protected areas totaling an area of over 537,465 ha. These protected areas constitute one of the largest tropical rainforest blocks in Madagascar and from the six main river systems within, they ensure the water supply of the SAVA, Sofia, and Diana regions. WWF is empowering six unions made up of 65 community forest associations known as COBAS (*Communautés de Base*), which will become relay organizations that in the near future will take on support and accompaniment roles (i.e., technical, organizations, and institutional). The technical training received from WWF includes forest management,



business accounting (e.g., the establishment of 73 community savings and loans groups), agricultural methods, lemur surveys, and literacy (Goodman et al., 2018).

It is also critical to support development and training (including providing tools and legal expertise) for community forest managers who conserve over 100 forest sites around Makira Natural Park and Masoala National Park. An increasing number of communities in the region are interested in receiving forest management tenure from the government of Madagascar. Forest management tenure provides individuals and communities with increased control over their natural resources such as permitting legal sustainable logging and charging fees for tourism and research. Near Marojejy, the LCF supports a growing number of private nature reserves (e.g., Antanetiambo, Agnolakely, Antohakalava, and Macolline) that were started by local conservationists, and now host tourists, students, and researchers. Similarly, the San Diego Zoo Wildlife Alliance (SDZWA) and Portland State University (PSU) train members of the newly-formed community-managed forest, Ravintsara, located adjacent to Masoala National Park, in forest and lemur monitoring methods. In collaboration with IMPACT Madagascar and the University of Antananarivo (UA), two local NGOs, Antongil Conservation and Fandroakando, have initiated conservation management of the Farankarina and Rabondro Forests, respectively. These neighboring forests are the site of a red ruffed lemur (*Varecia rubra*) reintroduction-translocation project.

## (2) Protect native habitats

Effective protection of native habitats requires supporting and training both individuals and institutions, for example, local branches of the judicial system, to correctly interpret environmental laws and enforce penalties for those caught conducting illegal activities within protected areas. Such support and training should also ensure full-time monthly salaries for the intense essential work of community rangers and local community forest protection associations (i.e., *Vondron'Olona Ifotony*, commonly known as VOI), and an understanding of how to include concepts of *fihavanana*, or solidarity and familial peacekeeping in communities, within their enforcement strategies, lest they interfere with infraction reporting and promote local social unrest. In addition, numerous protected areas in Madagascar have an insufficient number of park rangers (Schwitzer et al., 2013). Anjanaharibe-Sud Special Reserve, for example, has only five park agents patrolling 374.8 km<sup>2</sup> of mountainous rainforest. Moreover, patrols should work with local communities to collaboratively survey the interior and exterior of protected areas, identify current and potential threats, monitor lemurs and other fauna, monitor local ecology, and improve community-park relations. LCF organizes monthly 5-day patrol missions in Marojejy, which includes dozens of *Comité Local du Parc* and park agents. The Wildlife Conservation Society (WCS) has a management delegation in Makira Natural Park and uses SMART (SMART, 2022) to monitor threats and wildlife during c. 600 collaborative patrols per year with local communities, an action

that also has been taken by WWF in their management of COMATSA. Strengthened capacity to patrol, survey, and monitor in and around all northeast protected areas will help protect the environment and promote biodiversity conservation.

## (3) Reforest new and existing habitats

Forest restoration projects are critically important to restoring native habitats within the region. These efforts include forests in protected areas, their peripheral zones, and corridors between forest fragments. Furthermore, taking a landscape restoration perspective (e.g., reforestation initiatives that integrate native utilitarian trees) could be beneficial for both biodiversity conservation and local people (Konersmann et al., 2021). This strategy of improving matrix habitat and promoting connectivity should also integrate lemur food trees to promote wildlife dispersal (Eppley & Goodman, 2022; Steffens, 2020). Proof of this principle has been shown in northern Masoala through ruffed lemur seed dispersal (Martinez & Razafindratsima, 2014). Data presented by Martinez & Razafindratsima (2014) indicate that 75% of consumed fruit species (i.e., 41 species) are passed whole/intact by red ruffed lemurs and dispersed in both undisturbed and regenerating forest parcels. Natural forest regeneration efforts such as these can be an effective strategy for restoring landscapes at a lower cost than active tree planting and should be promoted wherever possible. Both LCF and WCS currently support tree nurseries and reforestation. In 2021, 30,000 seedlings were grown and planted around Marojejy and Anjanaharibe-Sud and 552,000 seedlings were grown and planted around Makira. The DLC supports reforestation in the SAVA region, partnering with local stakeholders, including farmers, the government, and even the military. Crucial to these efforts are collaborative agreements, cocreated with the stakeholders, outlining roles, responsibilities, and expectations by all partners. Following the best practices as outlined by recent reviews of landscape restoration activities (Brancalion & Holl, 2020; Di Sacco et al., 2021; Elias et al., 2022; INDRI [Initiative pour le développement la restauration écologique et l'innovation], 2022) between 2021 and 2022, five community reforestation projects planted over 110,000 seedlings on approximately 20 hectares. Restoration initiatives follow two general models. In the first, large-scale tree planting is done on communal land, identified by communities as areas to be set aside for the regeneration of forest. The second model focuses on distributing tree seedlings to individual farmers who plant them on their own farmlands. In both models, the local partners choose the tree species they identify as priorities, along with guidance provided by DLC and CURSA. These include native trees for the regeneration of forest, as well as fruit and cash crop trees. DLC provides technical and financial support for Malagasy staff, collaborators, and partners at CURSA to carry out these activities.

## (4) Establish long-term biological research and ecological monitoring programs

Lemur conservation requires applied data-driven scientific research that considers the context of protected areas as well as the needs of wildlife. Establishing and continuing collaborative

research and monitoring programs is an effective strategy for acquiring baseline data on flora and fauna, allowing local communities, park managers, and researchers to evaluate temporal patterns of anthropogenic pressure and climate change (Eppley et al., 2022). Andranobe Forest in Masoala National Park is home to the longest, continuously-run biological research station in northeast Madagascar (established in 1993). Broad biological monitoring occurred at Andranobe before the establishment of the park whereas long-term studies focus predominantly on red ruffed lemurs (Vasey et al., 2022; and refs. therein). The site has been a training ground for university students from Madagascar and the USA with recent studies examining forest and lemur responses to cyclonic weather and seasonality (Andriamahaiavana, 2020; Mogilewsky, 2020). Since 2017, SDZWA has partnered with PSU and the UA to continue work at Andranobe, conducting comprehensive population monitoring of red ruffed lemurs, which was first begun in 2007. Ruffed lemurs are indicator, umbrella, and flagship species, and addressing their survival requirements contributes to the survival of myriad other plant and animal species. Ruffed lemurs rely on a variety of species of exceptionally large trees to nest and stash their young in the canopy, so even selective logging likely causes ubiquitous local extirpations by impeding successful lemur reproduction (Vasey et al., 2018). The conservation directive is clear; with however many tree seedlings we plant, we must also do our utmost to protect mature native forests. Long-term monitoring also has been established by IMPACT Madagascar and UA researchers in the Farankaraina and Rabondro Forests to carry out postrelease behavioral ecology assessments of reintroduced-translocated red ruffed lemurs. The DLC has recently begun a collaboration with CURSA and WWF to engage students and faculty in ecological monitoring in the COMATSA protected area. A team of CURSA scientists are partnering with local forest managers to study lemurs and their habitats at nine sites around the COMATSA. The team also conducts social science research with communities bordering the forest to understand natural resource extraction in the area.

##### (5) Reduce food insecurity

Northeast Madagascar has the highest hunting pressure in all of Madagascar (Borgerson, Johnson, et al., 2022). Unsustainable hunting of wildlife depletes targeted species and potentially causes local extirpations, particularly of lemurs. Food security is a serious challenge for smallholder farmers. In three studies in the SAVA and Analanjirofo regions, up to 78% of households reported they had insufficient food during the previous years (Andriamparany et al., 2021; Borgerson et al., 2019; Herrera et al., 2021). Thus, it is perhaps not surprising that forest-adjacent communities often rely on wildlife to improve their nutrition and food security, when sufficient alternatives are not available (Borgerson et al., 2019; Golden et al., 2019).

Examples of studies designed to reduce food insecurity include those pioneered by the NGO Madagascar Health and Environmental Research (MAHERY). This has included work on

the Masoala Peninsula with Montclair State University, the Madagascar Biodiversity Center, and local communities, to codevelop, test, and train in methods designed to farm a native edible insect called *sakondry* (*Zanna tenebrosa*), to improve fat, caloric, calcium, protein, and iron intake and decrease pressure on wildlife (Borgerson et al., 2021; Borgerson, Aardema, et al., 2022). The success of this insect farming project in Masoala, as measured by low-cost improved nutritional outcomes and reduced endangered lemur hunting, has led to its replication in Makira by WCS and throughout the SAVA region by DLC. Furthermore, it has expanded to other regions where it has been replicated with enthusiastic success, for example, southeast Madagascar, where Montclair State University and SDZWA are working with local communities bordering Andohahela National Park. In addition, MAHERY, the Wildlife Health Network, and IMVAVET (Madagascar's Veterinary Vaccine Institute) have developed a thermostable vaccine to address Newcastle disease and improve poultry husbandry (Annapragada et al., 2019). The thermostable and affordable vaccine, first deployed in communities near Makira Natural Park and Masoala National Park, is now available nationally to improve poultry production, both supporting human nutrition and reducing pressure on wildlife.

On the edge of Makira Natural Park, WCS is also working with Center de Cooperation Internationale en Recherche Agronomique pour le Développement (CIRAD) to screen for zoonotic diseases in local human communities and to support farmer-to-farmer field schools for improved livestock husbandry techniques that reduce reliance on wild meat. LCF has supported numerous fish farming training workshops and maintains a model freshwater fish pond with a locally endemic cichlid fish, *Paratilapia polleni*. To address food insecurity and malnutrition in SAVA, in 2019 the DLC began training farmers in agroecology practices to improve vegetable garden productivity, with over 400 farmers in 12 communities engaged and half adopting new methods. Follow-up surveys and evaluations also led to the expansion of fish farming, with over 60 farmers involved, and chicken husbandry, with over 120 farmers trained. These efforts are aimed at developing resilience through diversified farming and animal husbandry that also create income-generating opportunities and have the broader aim of decreasing pressure on natural resources.

##### (6) Support environmental education

Exposure to basic levels of earth and environmental science education can encourage a deeper understanding of the value of nature and the services it provides. Understanding the diverse role of trees in the landscape helps link the need for reforestation with the services trees provide (e.g., flood and drought resilience, clean air, and erosion control). Yet educational opportunities are often limited for rural communities because only primary schools are accessible. Improving educational infrastructure, a key deficit whose impacts are felt severely in rural park-adjacent communities, helps to improve community-NGO relationships as we work toward shared goals.



The DLC has trained over 2600 teachers in the fundamentals of environmental sciences (including photosynthesis, the water cycle, and food webs) to empower teachers and communities to promote a greater appreciation for the endemic species in their own “backyard.” DLC has also developed a lemur awareness program led by local education specialists, in which the educators visit schools and deliver an interactive lesson plan focusing on the diversity of lemurs from the SAVA region, explaining that lemurs are not to be kept as pets or eaten, and why lemurs are important for the ecosystem. Motivated teachers have established environmental clubs, and received training and materials to develop their clubs' activities, which include tree planting and the creation of school gardens. Educators also bring students on trips to Marojejy National Park and a locally-run interpretive center called the New Generation School Garden. A quantitative assessment by LCF using cultural consensus analysis (Nekaris et al., 2018) found positive impacts of student field trips to Marojejy National Park, including an increase in positive emotions and knowledge about the park, and highlights the importance of “place-based” environmental education programs (Sorenson et al., 2021). WCS runs the Open Classroom Program in Maroantsetra, which organizes targeted and after-school environmental educational programs open to all regional students and national park field trips for local environmental clubs.

(7) Promote nature-positive sustainable livelihood opportunities

Community revenue-generating projects that encourage wildlife and land conservation and sustainable resource use are needed to reduce economic dependence on land and forest resources (e.g., ecotourism initiatives, health care and industry training, and certified forest-friendly cash crops). WCS developed the first farmer cooperatives in the Maroantsetra region, training farmers in agroforestry and cash crop production, including integrating cacao with food crops and native forest flora. Farmers are now exporting cacao to Switzerland, providing diversified revenue and encouraging others to adopt these agroforestry techniques. In addition, more than 326,100 seedlings of clove trees, fruit trees, and vanilla lianas were shared with local people around Makira Natural Park. Similarly, the DLC supports farmers in the creation of diversified agroforestry systems, including cloves, coffee, vanilla, pepper, and other perennial crops. Community-managed forestry, supported by WWF in COMATSA, also generates income through sustainable extraction and sales. Specifically, WWF has facilitated the integration of cash crop producers (more than 400 vanilla and 300 ginger producers) into a deforestation-free certification scheme through a direct contract with private companies.

Eco-tourism, a key strategy of the Lemur Action Plan, often has had a revenue-generating cascade effect. For example, visitors to Marojejy National Park generally spend several days and nights inside the park, renting bungalows, hiring porters, cooks and guides; however, this region of Madagascar remains one of the least visited. Marojejy received only 785 foreign tourists in 2019 which fell to zero in 2021 due to COVID-19 restrictions.

Improved infrastructure could draw tourists to protected areas (Ormsby & Mannle, 2006). Makira Natural Park communities manage an ecotourism site in collaboration with WCS, using their annual tourism revenue for community development, including running a health clinic and subsidizing teacher salaries. LCF created Camp Indri in Anjanaharibe-Sud, the only site with infrastructure for visiting tourists and researchers. More recently, Camp Mantella and Camp Marojejia in Marojejy, the most visited sites in this largely neglected region, also have been completely rebuilt after being closed due to cyclone damage. A new tourist-friendly website for Marojejy has also been created: <https://explorewildmadagascar.com/marojejy-national-park/>. It should be noted, however, that despite the positive impact that large numbers of tourists can have on local communities, they can also have negative impacts on protected areas and the surrounding environment, thus measures must be taken to prevent damage to these World Heritage Sites.

(8) Expand community health programs

The basic health care needs of the rural communities living near protected areas in this region are often unmet. Only a handful of hospitals and clinics exist, and it can take several days over rough terrain to reach the closest medical facility (Bustamante et al., 2019). Community health programs can contribute to forest conservation not only by building trust, but also by breaking cycles of poverty and poor health.

Duke University's Global Health Institute has studied many aspects of human health in this region with some surprising findings, such as high rates of hypertension (Manus et al., 2018). PHE programs have expanded greatly across Madagascar in recent years (Mohan & Shellard, 2014). DLC, LCF, and WCS have partnered with nurses from Marie Stopes International to provide voluntary family planning services, including contraceptive implants. Through DLC's collaboration with Marie Stopes Intl., over 2500 women from more than 30 villages received reproductive health care services within the SAVA region. Through LCF and WCS's efforts, 2100 women in 63 villages near Marojejy and 6000 families in 50 villages around Makira have received reproductive health care services since 2018. Furthermore, regional PHE conferences are held regularly, and the first annual PHE Day meeting took place in March 2021 in Sambava.

MAHERY and the affiliated research teams from the Harvard T.H. Chan School of Public Health have studied in detail the food systems and nutritional status of local communities, including the first-ever assessment of micronutrient deficiencies (Golden et al., *in review*). This assessment highlighted very high rates of zinc deficiency, and large burdens of iron, vitamin A, vitamin B<sub>12</sub>, and other deficiencies. Beyond wild foods sourced from the forest, the MAHERY team has also documented the traditional medicines sourced from the forest (Golden et al., 2012), and created the first US-copyrighted book written in Malagasy (Betsimisaraka dialect) preserving the oral history of traditional medicines with illustrations and recipes for the use of hundreds of different plant species to treat more than 80 different illnesses (Golden, Anjanirina, et al., 2014).

These teams have also carefully documented the prevalence of malaria in Makira and elsewhere (Rice et al., 2016, 2021), the distribution and abundance of larval mosquitoes that serve as vectors for infectious disease (Arisco et al., 2020), and ongoing research to evaluate the prevalence of mental health conditions including anxiety, depression, and trauma. Since 2014, the MAHERY team has been documenting health conditions for every individual in three communities in Makira and Masoala, assisting the work of the Ministry of Health in Madagascar. All of these health conditions are related to the present condition of the forest and are exacerbated by accelerating trends in ecosystem transformation.

## 4 | CONCLUSION

Drawing on diverse training we focus on eight goals and associated activities that have improved the coexistence and health of the environment, people, and lemurs in northeast Madagascar. Despite substantial progress made toward addressing these goals, we acknowledge that the scale of these efforts is woefully insufficient, and this diverse and important landscape remains overlooked and increasingly threatened. As conservationists, we must ensure that good governance promotes effective and synergistic economic and conservation development. In this remote region, these two must work hand in hand with one another to secure the combined futures of the region's people and biodiversity, lest the progress of one threatens the other. As individuals, there are a number of equally important actions that we can take to be better stewards of the environment. For example, we can purchase products that are independently certified as sustainable and avoid purchasing noncertified tropical timber by checking labels and the origins of any wood products. When traveling, we can visit and promote community-managed ecotourism sites that support forest conservation initiatives. As international researchers, we can also increase our efforts to meaningfully engage with and empower local communities. Such efforts may also extend to financial support through donations or volunteering to strengthen community-based conservation projects. If you are interested in the programs and initiatives detailed in this commentary, consider joining us in supporting and promoting lemur conservation through the links below.

- Save, protect, and care for lemurs and other endangered African wildlife when you give to the [SDZWA](#) African Forest conservation hub. Your generosity will support field-based conservation projects, providing training and capacity-building opportunities to community forest managers, forest patrols, and university students. Thank you for being an ally for wildlife!
- Make a donation to help support interventions which improve food security and reduce the unsustainable hunting of threatened lemurs by supporting Dr. Cortni Borgerson's team ([Full Forests Fund, Montclair State University](#)). 100% of donations will be used to train park-adjacent families in northeastern Madagascar to rear the traditional edible insect, *sakondry*, and to expand and improve upon proven strategies to reduce lemur hunting.

- Support conservation efforts by donating to [LCF](#). Donations help fund ecotourism infrastructure, forest patrol missions, fuel-efficient stoves to reduce pressure on forests, reforestation, providing access to medical and family planning health care, and environmental education programs.
- Support the [DLC SAVA](#) Conservation Program, including empowering farmers to diversify crops and promote regenerative agroecology techniques, landscape restoration, environmental education, fuel-efficient stoves, women's reproductive health, and supporting local university students to become the next generation of conservation scientists.
- Support the [WCS](#) MaMaBay Landscape, including management of Makira Natural Park, forest patrols, improved farming techniques including agroforestry with cash crops, rice intensification and small livestock husbandry, improving community access to health care and education, forest restoration, and developing and training community forest managers.
- Support the [MAHERY](#) team to finance three primary efforts: (1) training and mentoring Malagasy researchers in planetary health research; (2) scale and disseminate vaccinations to support poultry production to reduce wildlife hunting; and (3) provide human health monitoring of local communities to understand the multifold benefits of conservation activities and the potential risks of environmental change.
- Support [IMPACT](#) Madagascar and the red ruffed lemur reintroduction and translocation project in Farankaraina. Donations help to support post-release ecological monitoring of the lemurs, training of local guides, and supporting university student research.
- Support lemur conservation through PSU. PSU supports long-term lemur population monitoring and applied research, provides training and employment to Malagasy partners and staff, and helps prepare university students for environmental work. To donate, contact Dr. Natalie Vasey at [nvasey@pdx.edu](mailto:nvasey@pdx.edu).
- Support Madagascar conservation efforts through [WWF](#). Donations help to support community-managed forestry associations, upscaling of successful models of sustainable financing for conservation from private companies, community-saving and loans groups and commune authorities, diversification of households' revenues and the promotion of sustainable agricultural techniques.

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## CONFLICT OF INTEREST STATEMENT

All authors are employed by and/or serve in a professional role within the organizations/institutions whose programs are being advocated for in this article.

## DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no data were generated or analyzed.

## ORCID

Timothy M. Eppley  <http://orcid.org/0000-0003-1456-6948>

Cortni Borgerson  <http://orcid.org/0000-0003-3434-033X>

James P. Herrera  <http://orcid.org/0000-0002-0633-0575>

Christopher D. Golden  <http://orcid.org/0000-0002-2258-7493>

Charlotte Spira  <http://orcid.org/0000-0001-6296-1075>

Natalie Vasey  <http://orcid.org/0000-0002-0384-954X>

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