Introduction: The way of the future — new paleosciences research led by Malagasy scientists

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"*Ze tane mahavelo ka tanendraza.*"
"The land that sustains you is the land of the ancestors." (Vezo proverb)

The first publications engaging questions of Madagascar's past environments, flora, and fauna were authored by European travelers, naturalists, and colonial administrators beginning in the 17th century (e.g. Flacourt, 1658; Murchison, 1833; Strickland, 1849; Geoffroy Saint-Hilaire, 1851; Rowley, 1867; Grandidier, 1885; Forsyth-Major, 1893). In the intervening years scientific debates over changes in the island's environments have centered on the Holocene and particularly periods for which there is evidence of human presence on the island (Douglass & Zinke, 2015). These debates over human-environment dynamics were ignited—and in many ways sustained—by colonial era writing that strategically framed the land-use practices of Indigenous communities as unproductive at best and destructive at worst (Perrier de la Bâthie, 1921; Davis, 2007). Large-scale deforestation, the formation of *lavaka*—erosion gullies—and the extinction of endemic large-bodied fauna were all assumed to be the most visible and direct consequences of catastrophic land and resource-use practices by Malagasy communities (Humbert, 1927).

The influence of colonial-era thinking on the study of human-environment interaction on Madagascar is vividly illustrated in the debate over the origins and drivers of *lavaka* formation. *Lavaka* are dramatic erosional features of the landscape on the Central Highlands of Madagascar with vertical headwalls and no feeder channels. Proponents of human drivers of these erosion features argued that people were responsible for the creation of *lavaka* via extensive deforestation, overgrazing, and burning (Riquier, 1954; Gade, 1996). These arguments were based on exaggerations and assumptions, but they gained currency because they fed a colonial narrative designed to delegitimize Malagasy land-use (Kull, 2000; Klein, 2002). Meanwhile, teams of researchers—that included Malagasy scientists—demonstrated that initial *lavaka* formation far precedes the window of known human presence on Madagascar and is linked to a complex set of processes, including seismic activity, bedrock geology, and hydrology (Wells & Andriamihaja, 1993; Cox *et al*., 2010; Voarintsoa *et al*., 2012).

In recent decades, scholars engaged in the debate over how people have influenced and altered Madagascar's landscapes, flora, and fauna have conducted fine-grained studies of Madagascar's paleoecology, identifying early signs of human arrival and disentangling anthropogenic drivers of environmental change from climate and other processes (Burney, 1987). Such studies have engendered a critical awareness of the colonial roots of debating human-environment interaction on Madagascar (Kull, 2000; Pollini, 2010; Dewar & Richard, 2012). Although the assumption that the presence of Malagasy communities on the island has always signaled environmental decline still lingers (Douglass *et al*., 2019a), new research is improving our understanding of the co-evolution of people and landscapes through time by reassessing the chronology of human arrivals, changes in human land-use, and the interaction of both with climate (Douglass *et al*., 2019b; Godfrey *et al*., 2019), as well as the deeper-time evolutionary history of Madagascar's unique biogeography (Karanth *et al*., 2005; Yoder & Nowak, 2006; Dewar & Richard, 2007).

Advances in the Malagasy paleosciences, comprising the fields of paleoecology, paleoclimatology, paleontology, and archaeology, would not have been possible without the substantial and often unrecognized contributions of Malagasy scientists. Full acknowledgement of the contributions Malagasy communities and scientists have made to

Douglass, K., Godfrey, L. R. & Burney, D. A. 2021. Introduction: The way of the future — New paleosciences research led by Malagasy scientists, eds. K. Douglass, L. R. Godfrey & D. A. Burney. *Malagasy Nature*, 15: 2-6.

our knowledge of the island's past is long overdue. European and North American scholars have been credited—via their publications—with the bulk of the scientific knowledge production about Madagascar's past environments, despite the essential work of Malagasy researchers in planning and carrying out fieldwork, engaging place-based intergenerational ecological knowledge, curating specimen collections, analyzing samples, interpreting and disseminating results, and more. The under-appreciation of Malagasy contributions to science and amplification of the contributions of European and North American researchers has ultimately narrowed research agendas toward questions and concerns that do not capture the diversity of thought about Madagascar's past, and perpetuate colonial legacies in science.

This special issue of *Malagasy Nature* intentionally and exclusively features work led by Malagasy scientists and especially by Malagasy Early Career Researchers (ECRs) in the paleosciences. What began as an effort to offer mentorship to Malagasy ECRs through the publication of this special issue, quickly turned into an exercise in critical reflection on the persisting inequities in scientific training, resources, and publication in the field of Malagasy paleosciences. The choice of publishing this collection in *Malagasy Nature*, an international scientific journal published in Madagascar, follows one of the mandates of the journal to advance science on Madagascar for national researchers. For some contributors, this special issue represents a first opportunity to author or lead a peer-reviewed scientific paper. For many, existing barriers to accessing research funding, laboratories, and other support were exacerbated by the COVID-19 pandemic. Increasing diversity and representation in science, technology, engineering, and mathematics is a moral imperative, and the contributions to this special issue all highlight the tremendous gains the entire scientific community benefits from when diverse questions, theories, methods, and interpretations are generated. To our knowledge this special issue is unique in its centering of Malagasy ECRs as lead or sole authors in paleosciences research. Similar efforts to center and support local, Indigenous and descendant ECRs are necessary in other regions and across all scientific fields (Massey *et al.*, 2021).

This collection of papers covers a range of topics from paleoclimate and paleoecological reconstruction to theoretical modeling of intrinsic drivers of vegetation change and human settlement choice. Together they highlight the great potential of interdisciplinary approaches to studying Madagascar's past and the need for future efforts to increase interdisciplinarity and the diversity of scientists involved.

Rasolondrainy contributes an ambitious and theoretically innovative assessment of human settlement choice in the Isalo region of central southern Madagascar during the Late Holocene. Drawing on theories of human niche construction, Rasolondrainy investigates whether settlement patterns in the 16-19th centuries primarily reflect communities' efforts to position themselves in defensible locations, or a desire to be close to vital natural resources, or a combination. His work centers equally on archaeological, oral historical, and geospatial information to improve our understanding of the dynamics of environmental and climate change, intergroup conflict, and mobility in Madagascar's arid south.

Ramiadantsoa and Solofondranohatra provoke new thinking on the evolution of Central Highland vegetation communities during the Holocene. Long a topic of contested debate linked to hypothesized devastating human impacts on landscapes, vegetation change has primarily been investigated from the perspective of extrinsic drivers of change. Here, the authors draw from theoretical ecology to develop a mechanistic model of vegetation change based on intrinsic dynamics of coexistence and competition between three vegetation types—forests, fire-maintained grasslands, and grazing-maintained grasslands. Their results suggest that intrinsic dynamics may have had significant effects on the expansion of grasslands and contraction of forests, with important implications for debates over human-driven changes in landscapes and biotic communities.

Razanatsoa and colleagues make an important contribution to our understanding of human adaptation to climate change and the urgency of supporting autochthonous strategies of land use and resource management given intensifying climate change. Their work examines a sediment core from the Mikea region of the southwest and describes human response to two pronounced droughts in the 14th and 20th centuries. They conclude that the ability of local communities to adjust subsistence practices in ways that utilize the diversity of forest resources increased resiliency to drought. The lessons from this case study should inform policies of resource and land use in the region and elsewhere and encourage governments and organizations to support the self-determination of local communities as they develop autochthonous strategies to cope with climate change.

Voarintsoa reviews the findings from $\delta^{18}O_c$ in stalagmites from caves in northwestern Madagascar and relates these results to other types of paleoclimatological data. By comparing the reconstruction to existing climate models for the western Indian Ocean region, she shows the importance of monsoonal dynamics as a driver of seasonality on Madagascar. The explanations of the role of each step in the process of stable isotope deposition in caves and how this relates to climatic reconstruction provides a much-needed primer for investigators conducting parallel research and for students who might be interested in pursuing this emerging subject.

Ramarolahy and colleagues re-examine the much-studied subfossil site of Taolambiby in the southwest. Their paper provides the first detailed sediment description for a complete profile of the rich subfossil-bearing layers of this site. Through analysis of pollen, spores, and charcoal particles, the authors document fluctuations in the climate around Taolambiby over the past several thousand years, including a spike in aridity ca. 1500 yr BP. About this time, abundant evidence shows that humans were hunting at several sites in the southwest, and that Madagascar's populations of large-bodied fauna—including large lemurs, hippopotamuses, and elephant birds—were collapsing. It would appear from this combination of evidence that human activities and late Holocene climate change each played a role in the subfossil extirpations in southwestern Madagascar.

Rakotozandry and colleagues examine crocodilian material from a new subfossil site (Tsaramody, Sambaina Basin, central Madagascar), comparing these specimens to previously published and unpublished subfossil material from Tsimanampesotse, Taolambiby, and Ampasambazimba. Recent studies of some of the largest of Madagascar's extinct vertebrates (elephant birds and hippopotamuses) have resulted in reassessments of their taxonomic diversity across Madagascar, but similar attention has not been paid to the endemic extinct crocodiles. Whereas the authors show that the Tsaramody subfossils belong to the recently extinct endemic "horned" crocodile, *Voay robustus*, they also provide evidence for extensive variation in this species across a broad distribution. They highlight the value of revisiting existing collections to help contextualize patterns of variation in a paleoecological context.

Faina and colleagues present the first high-resolution reconstruction for the past 3000 years of changes in the hydroclimate of Madagascar's southwest on the basis of stable isotopes from a well-dated stalagmite collected at Asafora Cave (Morombe District, southwestern Madagascar). The authors also compare these records to high-resolution records of hydroclimate change from the northwest to determine whether or not Madagascar experienced island-wide climate fluctuations in the Late Holocene. This is a critical period as it includes the time when human populations began to grow in the region, cultivated plants and domesticated animals were introduced to Madagascar, and populations of many endemic, large-bodied species crashed. This study focuses on the potential influences of climate change and human activities in triggering that loss.

Rasolonjatovo and colleagues identify the rich subfossil bird remains from Vintany Cave, one of the flooded caves at Tsimanampesotse National Park. While many of the bird species whose remains have been recovered at this site still live in the park, the fossils also include five extinct and two extant but locally-extirpated species. The authors examine the paleoecological implications of the temporal change in the composition of the avifauna at this site, particularly the loss of freshwater species. They discuss the possibility that aridification and lake salinization contributed to the decline or disappearance of some of these species.

Rahantaharivao and colleagues present, for the first time, data on the size of the brain and on craniodental and postcranial growth and development of one of the large-bodied extinct lemurs of Madagascar, *Pachylemur insignis*. They provide new data on its dental microstructure and the relative rates of growth and development of various body parts, and they discuss the phylogenetic, ecological, and life-history implications of their data. The authors ask whether this largest member of the family Lemuridae grew like similarly-sized monkeys or apes, or like their much smaller-bodied, still-extant relatives. The overwhelming signal is that, despite its large size, *Pachylemur* grew and developed like the living lemurs to which it is most closely related, such as ruffed and ring-tailed lemurs.

Nomenjanahary and colleagues present the stories and accounts told by the local people of the Montagne d'Ambre about a large-bodied (estimated ~25 kg) carnivoran that, some say, may still live in the forests of this park. These authors explore the possibility that the large-bodied carnivoran is the "extinct" euplerid, *Cryptoprocta spelea*, and they extol the potential of traditional ecological knowledge to improve our understanding of the decline and extinction of rare species. As stated by the authors themselves, "when these stories, eyewitness accounts, and science are combined, they may give 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." Their paper emphasizes the need to integrate local communities and community knowledge intimately in conservation science, if efforts to conserve the remaining natural habitats are to be successful.

As highlighted in our opening, there are many important takeaways and invitations for critical reflection about the representation of diverse scholars in the paleosciences. It is also noteworthy that these new findings from diverse studies by young Malagasy investigators are already finding new synergistic connections. For instance, Ramarolahy *et al*. cite three other papers in this volume: Faina *et al*. provide the most precise paleoclimate data yet available for southwestern Madagascar from a stalagmite, for comparison to the parallel inferences from palynological and sedimentological data from Taolambiby, showing excellent agreement. Voarintsoa is also cited in this paper in connection with the role of climate modelling in showing that monsoonal dynamics for northwestern Madagascar would not be expected to produce the same paleoclimatic patterns in the southwest, a point well-illustrated by the new findings from Faina *et al*. Also, Ramarolahy *et al*. point out that the decline of freshwater-adapted bird species reported in the study of Rasolonjatovo *et al*. published here supports the sedimentary evidence for drier conditions by the middle of the first millennium CE.

The co-editors of this volume are grateful to the contributing authors for their hard work and persistence, and to the many Malagasy mentors and colleagues who have helped these promising young scientists achieve their commendable level of scholarship. In particular, we dedicate this volume to our Malagasy colleagues who are no longer with us, including:

In Memoriam

Zafy Maharesy Dieu Donné Chrisostome
Fulgence Fanony
Barthélémy Manjakahery
Jean Gervais Rafamantanantsoa
Henri Rakotoarivelo
Berthe Rakotosamimanana
Gisèle Randria

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