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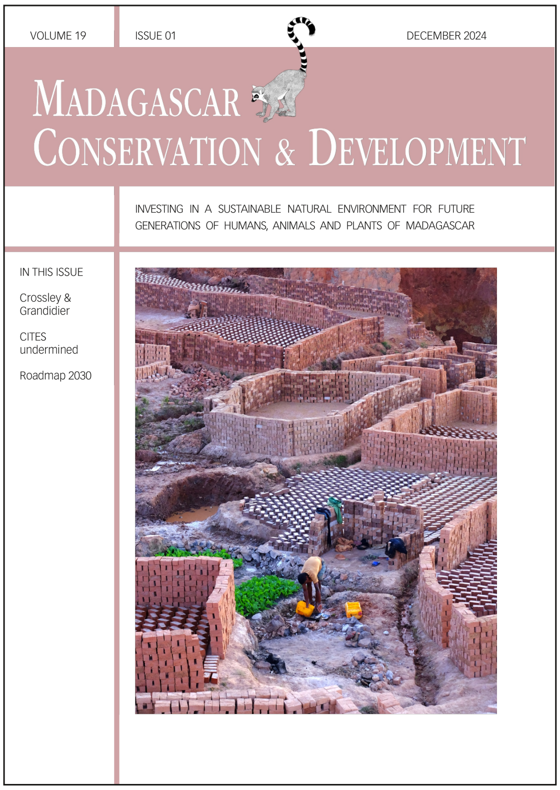
MADAGASCAR CONSERVATION & DEVELOPMENT

INVESTING IN A SUSTAINABLE NATURAL ENVIRONMENT FOR FUTURE GENERATIONS OF HUMANS, ANIMALS AND PLANTS OF MADAGASCAR

IN THIS ISSUE



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Madagascar Conservation & Development
Institute and Museum of Anthropology
University of Zurich
Winterthurerstrasse 190
CH-8057 Zurich
Switzerland

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Missouri Botanical Garden (MBG)
Madagascar Research and Conservation Program
BP 3391
Antananarivo, 101, Madagascar

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Madagascar towards 2030: navigating progress and challenges for nature and people

Growing calls within the science-policy arena are calling for doing away with reformist approaches that fail to address the underlying causes of biodiversity loss and engage in an overhaul of how biodiversity conservation is practiced, moving from reform to transformation (IPBES 2024). The urgency of this push stems from the recognition that incremental change under the current business-as-usual trajectory will not deliver the systemic transformation that the global state of the environment needs (Palomo et al. 2024). Madagascar epitomises this situation, particularly given the intricate relation between biodiversity and human development in the country.

Just as the front cover of this year's issue, progress on conservation and development in Madagascar occurs by incremental steps, with the ever-present possibility that a cyclone—or a political crisis, or global pandemic—washes away overnight the hard-won gains painstakingly built. Nearly two decades ago, the MCD journal was launched with the objective of providing a forum to examine the most pressing challenges biodiversity conservation and human development face in the country, while fostering debate on potential solutions. As we enter the second half of the decade and its many conservation and development goals rapidly approaching, it seems pertinent to take stock of the progress of the country. Loosely following the Sustainable Development Goals (SDGs) and the Kunming-Montreal Global Biodiversity Framework (KM-GBF), I will look at several pervading challenges, and distil some innovative ideas proposed recently, which hopefully, can help to make a difference for Madagascar's people and nature in the coming years.

TOWARDS THE SUSTAINABLE DEVELOPMENT GOALS?

While most SDGs have an indirect link to biodiversity conservation in Madagascar, these lines will be devoted to some with a more direct relation. Given that much of forest loss in the country is due to conversion of forest to (subsistence) agriculture (Waeber et al. 2015, Zaehringer et al. 2015), starting with SDG 2 (Zero Hunger) seems appropriate. Undernourishment in Madagascar declined up to the early 2010s reaching a low of 25%. However, it has since risen sharply, now affecting 40% of the population, while daily protein intake has also slightly decreased (FAOSTAT 2024). While the potential of locally-led innovation platforms to drive increases in agriculture performance has been recently highlighted (Audouin et al. 2023), agricultural land productivity in Madagascar remains among the world's lowest (Global Yield Gap Atlas 2024), with little improvement in sight (Dröge et al. 2022). In addition to fish farming, with a long tradition on the island (Angermayr et al. 2023), some promising ideas are being proposed to address the lack of protein intake. For example, cricket and planthopper farming and consumption are being promoted in several regions, harnessing the insect-consumption tradition in the country (Dürr et al. 2020, Borgerson et al. 2022a), while trying to reduce hunting pressure on lemur populations (Borgerson et al. 2022b).

The vast majority of Malagasy people still rely on solid biomass for cooking—charcoal in cities and firewood in rural areas (Montagne et al. 2010). This has serious consequences for both forests across the country (Gardner et al. 2016, Ramarokoto et al. 2024) and human health, as domestic air pollution ranks the second cause of disease in the country (Dasgupta et al. 2015), particularly affecting children and women (Jestin-Guyon et al. 2015). While achieving SDG 7 (Affordable and clean energy) remains distant, inspiring approaches have been tested in the last decades. On the fuel use efficiency side, innovations such as improved stoves or solar cookers (which use no fuel at all)—largely spearheaded by the NGO ADES for over 20 years—can reduce fuel consumption by up to two thirds (Vetter 2006, Andrianaivo and Ramasiarinoro 2014), while improved essential oils stills can cut firewood use by nearly half (Cœur de Forêt 2021). On the supply side, increased efforts have been placed on expanding plantations for fuelwood production (Bucht 2015). However, these initiatives remain at small scale in many regions (Blanco et al. 2019), which calls for increased efforts to harness the potential of this relatively low hanging fruit to reduce forest degradation.

Regarding SDG 8 (Decent jobs and economic growth), GDP per capita has mostly stagnated at around $US500/person during the last two decades, with population living under $US2.15 /day still standing at over 80% (World Bank 2024). Further, the promise of tourism, whose revenue plays a key role in the Malagasy economy (Cooke et al. 2022), was again shuttered by the COVID-19 pandemic and the measures put in place to arrest the spread of the virus across the country. Chiefly, these were the ban on interregional movement (Rakotonanahary et al. 2021), and specially the closure of the international borders for 20 months, with subsequent implications for tourist arrivals and related revenue streams (Harisoa and David 2023). Implications for local livelihoods could have been severe, particularly on those populations most relying on tourism and hospitality (Piquer-Rodríguez et al. 2023), exacerbated when impacting on communities reeling by the effect of cyclones or cash crop price crashes (Rakoto Harison et al. 2024). In this way, the relatively small role tourism plays in funding protected areas regarding the budget needed has prompted recent calls for increasing the resilience of protected areas by reducing the dependency on tourism flows that can just be shut down overnight in the event of an unforeseen crisis, as a global pandemic or a national political crisis (Andrianambinina et al. 2023).

Regarding SDG 12 (responsible consumption and production), recent work has underlined agroforestry's role for sustainable development. While crops typically produced under agroforestry regimes accounted for over a quarter of Madagascar's export value in the past 10 years, and provide income for at least half a million farmers (Andriatsitohaina et al. 2024), these systems hold great potential for restoring biodiversity in former shifting cultivation fal-

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lows (Wurz et al. 2022). However, scalability of agroforestry remains constrained by deficient infrastructure and consequent limited market access, insecure land tenure discouraging farmers to engage into costly investments to initiate production, or lack of know-how all together, all of which will need to be addressed if agroforestry is to realize its potential to deliver sustainable development for a larger share of Malagasy rural inhabitants. Further, the contradictory impacts the recent vanilla price boom (2015–2019) had on communities and forest alike (Llopis et al. 2019, 2022) should serve as a cautionary tale about the complex governance issues that commercial agriculture at the forest frontier faces in Madagascar, perhaps most starkly illustrated by the Menabe region, witness to one of the most dramatic forest loss processes in recent times (Rasoamanana et al. 2024).

PROGRESS IN CONSERVATION: AFTER AICHI, HEADING TO KUNMING VIA MONTREAL

Although Madagascar missed most of the Aichi targets for 2020 (Ralimanana et al. 2022), the country has made timid progress towards some of the 23 KM-GBF targets for 2030. For example, the share of terrestrial Key Biodiversity Areas enjoying some type of protection increased from 20.4% to 26.6% in the past 20 years, reaching a promising 49.1% in the case of freshwater areas (United Nations 2024). Much of this progress towards KM-GBF Target 3 (conserve 30% of land, waters and seas) is attributable to the Durban vision launched in 2003, leading to the creation of at least 75 new protected areas across all forest ecosystems in the country (Gardner et al. 2018), some of which have played a key role in conserving forests (Papunen and Eklund 2024). However, many of these new protected areas have become 'orphan sites', lacking management on the ground after former managers relinquished their responsibilities (Waeber et al. 2020). Moreover, many of those with actual management are severely understaffed (Rakotobe and Stevens 2024), and underfunded (Eklund et al. 2022), undermining achieving both Target 3 and 1 (plan and manage all areas to reduce biodiversity loss), and proving that Target 19 (mobilizing $200 Billion per year for biodiversity) remains a distant dream. This calls into question the need for further expanding the Malagasy protected area system without first addressing the pervading management issues afflicting the existing conservation schemes.

Madagascar has also seen a threefold increase in the area degraded between 2000–2015 and 2016–2019 (United Nations 2024), making ever more difficult achieving Target 2 (restore 30% of all degraded ecosystems). Despite increasing attention to forest and landscape restoration initiatives in the country (FAO 2024), and the long trajectory of some restoration initiatives (Mansourian et al. 2018), these are mostly yet to bear fruit, not the less because of the complicated tenure issues to be work out in Madagascar to deliver restoration at scale (Rakotonarivo et al. 2023).

Regarding KM-GBF Target 15 (businesses assess, disclose and reduce biodiversity-related risks and negative impacts), recent years have brought surprising findings regarding mining (both industrial and artisanal), traditionally considered a major driver of forest degradation and loss in the country (Eckert et al. 2024), and with potential for severe social implications (Ballet and Randrianalijaona 2014, Zaehringer et al. 2024). For example, efforts to offset the environmental impacts of the largest industrial mining operation on the island might be working (Devenish et al. 2022), although these gains might just vanish if not properly monitored by the State (Hubert Ta and Campbell 2023), or the mining corporation does not perceive economic gains from these activities. However, while overlaps between areas of potential gem occurrence and those with high biodiversity value might pave the road for further conflict between conservation and economic development, the vast majority of areas with gem potential are outside biodiversity-relevant areas (Devenish et al. 2023). Given that the impact of artisanal mining on forests may be less dramatic than once thought, this potential could be tapped for economic community development if, as challenging as it might be, adequate governance structures are devised (Devenish et al. 2024).

Honoring somehow KM-GBF Target 22 (ensure participation in decision-making and access to justice and information related to biodiversity for all), Madagascar is ever more relying on community-based approaches to manage natural resources (Reibelt and Nowack 2015), particularly around newly established protected areas (Gardner et al. 2018). However, community-based forest management initiatives may be subjected to higher pressures than conservation schemes such as national parks when under strain from the recurrent political crises impacting the country and their aftermath, as recently found by Neugarten et al. (2024). Further, despite the role that small scale, locally-led protected areas can play for increasing local sources of income through tourism (Cooke et al. 2022), only the more accessible sites might be capable of reaping these benefits (Rodríguez-Rodríguez et al. 2024).

While the need for strengthening capacity building in conservation (KM-GBF Target 20) has been repeatedly stressed (Eklund et al. 2022, Rakotobe and Stevens 2024), the conditions the COVID-19 pandemic imposed led to developments that allow to extract important lessons for the future of conservation research and practice in the country. The closure of Madagascar's borders implied that most international researchers and practitioners could not travel to Madagascar, forcing conservation and environmental education projects to rely more heavily on local expertise and resources, and local staff stepping into more leadership roles (Razanatsoa et al. 2021). This brought to the fore the urgency to increase the involvement of local communities to build and maintain project resilience in the face of unexpected crises, by improving access to technologies and training, and addressing equity and inclusivity aspects (West et al. 2023).

Finally, enhanced availability and accessibility of knowledge on biodiversity (KM-GBF Target 21) might be an increasing reality for Madagascar, if number of publications serves as an indication. A search conducted on Scopus on 16 December 2024 using the string "Madagascar AND (biodiversity OR "biological diversity")" returned 1,270 items (beginning in 1974), with increasing numbers from 11 records in 2000 to 96 in 2024. Importantly, half of these publications were published Open Access, also incrementally (from 27% in 2000 to 69% in 2024), and critically, with a third of all publications featuring authors with Malagasy affiliations, again with increasing frequency (from 27% to 47%). In parallel, the articles published from 2006 by MCD (not listed in Scopus) were 183, showing that this journal has been and remains a vital platform for exploring Madagascar's conservation challenges and advance innovative solutions for them.

WHICH WAY FORWARD THEN?

Madagascar's many challenges will not be solved overnight and with one-size-fits-all solutions, but from the array of approaches recently proposed, some that may be worth exploring are the following. For example, the feasibility of a conservation basic income is being currently assessed in northeast Madagascar (Wyss Academy 2024). This type of direct cash transfer aims at reducing the need to engage in environmentally destructive activities (de Lange et al. 2023) is gaining popularity among conservationists (Sheehan and Martin-Ortega 2023). While not yet tested at scale, its implementation could mark the beginning of a new era in conservation practice, where poverty alleviation and biodiversity protection are pursued simultaneously through socially equitable mechanisms. Similarly, as challenging as it may be governance-wise, schemes that allow local communities benefit from a well-regulated wildlife trade (Ganzhorn et al. 2014), as well as from the mineral reserves under their lands (Devenish et al. 2023), should be explored. Further, transparency about and accessibility to evidence on project outcomes—monitored through rigourous impact evaluation—should be increased, so we can learn about what works and under which conditions, and particularly what does not, and what went wrong in each occasion, so the very limited funding available for conservation and development is used wisely. Finally, the recent pandemic has shown us that the current models of mostly Global North-led conservation and development interventions are not only unequitable, but also not fit to face the crises that so often sever flows of people and resources between Madagascar and North-based organisations. With increasing numbers of students in the country choosing conservation-related disciplines, the new generation of Malagasy researchers and practitioners is probably the best prepared of all times to take leadership positions across all organisational levels. This transition will also require a fundamental shift in how research partnerships are structured and funded, moving away from extractive models that perpetuate dependencies towards genuinely equitable collaborations (Rakotonarivo and Andriamihaja 2023).

So the critical question remains: what will Madagascar's path towards 2030 look like? Will the last events in Madagascar be the catalyst for systemic change we were waiting for, or will business-as-usual be the path we continue to follow? The stakes for people and nature in Madagascar could not be higher. It is crucial that we choose the next actions wisely, so that, together, we can ensure the lessons of the past guide us towards a sustainable and inclusive future.

Jorge C. Llopis
Institut de Géographie et Durabilité, University of Lausanne, Switzerland
&
Centre for Development and Environment, University of Bern, Switzerland
jorge.llopis@faculty.unibe.ch

Figure 1. The 17 Sustainable Development Goals (top) and the 23 Kunming-Montreal Global Biodiversity Framework targets (bottom).

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Alfred Crossley and Alfred Grandidier: an enduring mystery of early natural history collecting in Madagascar

Ian Tattersall[1]

Correspondence:
Ian Tattersall
American Museum of Natural History
200 Central Park W
New York, NY 10024, USA
Email: iant@amnh.org

ABSTRACT

During the mid-nineteenth century the English naturalist Alfred Crossley and the French geographer Alfred Grandidier both made seminal contributions to our knowledge of the natural history of Madagascar. But while Grandidier published voluminously on the island's geography, ethnography, and fauna, Crossley has been almost completely written out of the record. Indeed, apart from the few original specimen labels that have survived, much of the little we do know about him and his itineraries in Madagascar (key to the utility of his extensive collections) comes from the scattered hints in Grandidier's publications and private notebooks summarized here. Even the nature of the relationship between the two naturalists, and the length of their acquaintance, remain obscure. In early 1870 Grandidier published new primate and bird species from the "forêts est d'Antsihanaka" on the basis of specimens lately obtained by Crossley somewhere southeast of Lake Alaotra; but although a close reading of Grandidier's unpublished private journals indicates that both naturalists had been in very close proximity in the Alaotra basin in mid-October of 1969, it appears that they did not actually encounter each other there, and it remains a mystery how and under what circumstances Grandidier obtained Crossley's Antsihanaka specimens – which, tragically, were almost certainly lost soon thereafter in a warehouse fire in Réunion. Evidence exists that Grandidier respected the latter's unique and extensive Madagascar knowledge and experience and subsequently sought Crossley's advice. But it seems that ultimately the social barriers that separated the wealthy Grandidier from the impecunious Crossley precluded a potentially fruitful working relationship – and left the latter an important but frustratingly spectral figure in the history of natural history collecting and in the biogeography of Madagascar.

RÉSUMÉ

Au milieu du XIX^{e} siècle, le géographe français Alfred Grandidier et le naturaliste anglais Alfred Crossley ont tous deux apporté des contributions déterminantes à notre connaissance de l'histoire naturelle de Madagascar. Mais alors que Grandidier publiait abondamment sur la géographie, l'ethnographie et la faune de l'île, Crossley a été presque complètement effacé des archives. En effet, à l'exception des quelques notes sur des spécimens qui ont survécu, la plupart du peu que nous savons de lui et de ses itinéraires à Madagascar (clé de l'utilité de ses vastes collections) provient d'allusions éparpillées dans les publications et les carnets privés de Grandidier résumées ici. Les commentaires publiés par Grandidier suggèrent que Crossley a peut-être travaillé comme collectionneur à Madagascar dès 1865, bien qu'il n'y ait aucune preuve solide de cela avant 1869. De même, la documentation de Grandidier sur les voyages de Crossley cesse après 1872, même si l'on sait que les deux hommes se sont rencontrés aussi tard qu'en 1876, l'année précédant la mort du naturaliste anglais à Madagascar. La nature de la relation entre les deux naturalistes reste aussi obscure que la durée de leur connaissance. Au début de 1870, Grandidier publia de nouvelles espèces de primates et d'oiseaux (dont *Cheirogaleus crossleyi* et *Bernieria crossleyi*) des « forêts est d'Antsihanaka » sur la base de spécimens récemment obtenus par Crossley quelque part au sud-est du lac Alaotra ; mais bien qu'une lecture attentive des journaux privés non publiés de Grandidier indique que les deux naturalistes avaient été très proches dans le bassin de l'Alaotra à la mi-octobre 1969, il semble qu'ils ne se soient pas réellement rencontrés là-bas, et il reste un mystère comment et dans quelles circonstances Grandidier a obtenu les spécimens d'Antsihanaka de Crossley—spécimens qui, tragiquement, ont presque certainement été perdus peu de temps après dans l'incendie d'un entrepôt à La Réunion. Il existe des preuves que Grandidier respectait les connaissances et l'expérience uniques et étendues de Crossley à Madagascar, et qu'il a par la suite demandé ses conseils. Cependant, il semble qu'en fin

1 American Museum of Natural History, 200 Central Park W, New York, NY 10024, USA

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de compte, les barrières sociales qui séparaient le riche Grandidier de l'impécunieux Crossley ont empêché une relation de travail potentiellement fructueuse – et ont fait de ce dernier une figure importante mais spectrale dans l'histoire de l'histoire naturelle et dans la biogéographie de Madagascar.

INTRODUCTION

Madagascar has for centuries been known for the uniqueness and rich diversity of its animal and plant life. It is, as Alison Jolly once luminously put it, "an island, a continent, a world, complete in itself … that tells us which rules would still hold true if time had once broken its banks and flowed to the present down a different channel" (Jolly 1980, p. xiii). Despite this singularity, systematic natural history collecting began in Madagascar only during the 1860s, thanks both to a long-awaited political opening to the outer world and to the efforts of several pioneering naturalists. The Dutch explorers François Pollen and Casparus Van Dam collected in the island's northwest between November 1863 and July 1866 (and the latter in the western region in 1869 and 1870); the French geographer and naturalist Alfred Grandidier conducted three visits to the east, south, west and center of Madagascar between 1865 and 1870; and the English collector Alfred Crossley made several journeys to the island between 1869 (or perhaps earlier) and 1877.

The uncertainty over Crossley's Madagascar dates stems from several factors (Tattersall 2022). It is known from an obituary published in his hometown of Halifax, in Yorkshire, that the naturalist's first foray to the island was involuntary, the result of a shipwreck that most likely occurred in the late 1850s and was followed by two years of probable enslavement (Anon. 1877) during the final, most xenophobic, years of Queen Ranavalona I's rule. Crossley's next documented activities in Madagascar, in the role of professional natural history collector at a time when foreigners had been readmitted, are first definitely recorded in 1869 (but might have been begun as early as 1865); and several other visits followed before his death at Tamatave on February 28, 1877, at the age of 37. His expeditions yielded a significant bounty of specimens, many of which are housed today in major European natural history museums (most notably those in London, Paris, and Leiden), though much of what he collected was sold privately and is probably now lost. The Crossley collections include numerous holotypes, several of which were named after their finder; but to the great detriment of science almost all of Crossley's specimens were dispersed through dealers who appear to have negligently discarded much, or even all, of the documentation that the collector apparently routinely furnished along with them (the few exceptions ironically going directly to a sponsor who also neglected to record their localities).

Crossley's involvement with commercial dealers contrasted with the prestigious institutional affiliations of the other early Madagascar collectors, and seems to have been largely the result of his chronically impecunious circumstances and lowly social status: attributes that also explain, at least in part, why he attracted so little personal, bureaucratic, or scientific attention during his extensive travels, even as he was making a long string of scientifically significant discoveries (Tattersall 2022). Biologists such as the British Museum (BMNH) ornithologist Richard Bowdler Sharpe were happy to describe Crossley's specimens, and at one point Sharpe (1875, p. 70) enthused that the Yorkshireman's "investigations in the wonderful island of Madagascar will forever connect his name with the natural history of that part of the world." But a mere four years later a curt reference to "the late Mr Crossley" (Sharpe 1879: 177) sufficed as a belated announcement to science that it had lost an exceptional naturalist. Sadly, although Crossley apparently kept extensive collecting records that we glimpse in Sharpe's brief but frequent allusions to them, no field notes have survived; and the naturalist published nothing during his short career. Without formal education he evidently lacked both the confidence and the social standing to publish, and a very unassuming personal disposition (Anon. 1877) probably also contributed to his reticence. As a result, a large stock of irreplaceable knowledge doubtless died with him.

ALFRED CROSSLEY AND ALFRED GRANDIDIER

Apart from his poorly documented collections, and Sharpe's brief references to his activities, our main source of published information on Alfred Crossley's travels in Madagascar is his French contemporary Alfred Grandidier, a wealthy Correspondent of the Muséum national d'Histoire naturelle (MNHN) in Paris. Grandidier traveled in various regions of the island in the same broad time frame as Crossley, collecting natural history specimens along the way with the "aim of assembling long series of all the animals of Madagascar" (Grandidier 1885, p. iii) for ultimate donation to the MNHN. His collections now form the backbone of the MNHN's Madagascar faunal and ethnological holdings, although but for circumstance they might be more extensive. Faure et al. (2019) report that when Grandidier left Madagascar (for what would turn out to be the last time) in late August 1870 (via the Seychelles, instead of via Réunion as anticipated, because of the outbreak of the Franco-Prussian War), he found himself obliged to abandon much of the collection he had amassed during his third Madagascar visit and had temporarily deposited at Réunion's St Denis Museum. Before they could be sent on to France, those specimens were destroyed in a fire. Undeterred, Grandidier subsequently devoted much of the rest of his life to producing his *Histoire Physique, Naturelle et Politique de Madagascar*, a lavishly illustrated multi-volume series on the island's history, geography, ethnology and natural history. This astonishing work is truly his monument, and it eloquently explains why, a century and a half later, his name remains synonymous with the natural history of Madagascar.

In an 1892 revision of the *Géographie* volume of the *Histoire* (Vol. 1: Grandidier 1885, confusingly issued after several other volumes of the series had already been published), the French naturalist supplied a long but evidently incomplete list of the itineraries followed by visitors to Madagascar between the late sixteenth century and 1890. Among those itineraries, he recorded that Alfred Crossley made several journeys in diverse regions of the island between 1869 and 1872. The first of those forays began in the far northeast, presumably at the port of Vohémar (although Crossley and Grandidier also used the name Vohima/Vouhima to refer to the extensive former Province that was governed from the town), and continued south along the east coast before cutting across the Masoala Peninsula to Maroantsetra, at the head of the Baie d'Antongil. Later in 1869 Crossley went from somewhere around Fénérive (Fenoarivo), via the principal port of Tamatave, to the "Pays d'Antsihanaka," the region around Lake Alaotra occupied by the Sihanaka cultural group. In 1870 Grandidier had Crossley journeying from Antsihanaka to the "Pays d'Imerina" around the capital city of Antananarivo, and in 1871 from Maroantsetra inland to Mandritsara, then south to Antsihanaka. Finally, in 1872, Grandidier records that Crossley traveled south from

Tamatave to Mahanoro and Mananjary, thence continuing inland to Ambohimanga Atsimo and Ambohimitombo before later traveling from Ankavandra to Mahajanga. See Figure 1 for a map of known Crossley localities in Madagascar. It may be relevant to note that at this period all travel inside Madagascar was on foot, in a palanquin, or by canoe.

The Crossley itineraries cited by Grandidier seem to be accurate as far as they go (Tattersall 2022). But they are very clearly incomplete, even for the years indicated; and the French naturalist records nothing for Crossley after 1872, even though we know beyond doubt that the latter made an important visit to Madagascar in 1874–5 and an ill-fated final one in 1876–7, and Grandidier elsewhere suggests that Crossley had been collecting in Madagascar well before 1869. To complicate matters, it remains uncertain how Grandidier got his information about Crossley, or indeed even whether there was any direct contact between the two naturalists before 1876. A letter (in French) from Grandidier to Richard Bowdler Sharpe is dated 30 July 1875 and requests news of the English collector, the strong implication being that the English and French Madagascar explorers had already interacted at some point, but that by 1875 contact had been at least temporarily lost. Grandidier's interest in Crossley in 1875 was almost certainly related to his desire to know more about the crowned sifaka *Propithecus coronatus*, a species known at the time only from specimens independently collected in northwestern Madagascar by Crossley and Van Dam. As one of only three species of its genus that Grandidier recognized, the crowned sifaka was a major subject of the imminent volume of the *Histoire* devoted to the indriid lemurs (Volume VI: Grandidier and Milne-Edwards 1875).

Figure 1. Map of Madagascar, showing main towns and localities associated with Alfred Crossley. Drawn by Patricia Wynne, from Tattersall (2022).

Grandidier's appeal to Sharpe for information was evidently successful. In a letter dated 15 December 1876, and sent to subscribers to the *Histoire* along with a revised distribution map of the sifakas, Grandidier records having visited Crossley in Halifax (and Van Dam's boss, Hermann Schlegel, in Leiden) to obtain more information about the crowned sifaka. Given what we know of the English collector's travels, the visit to Halifax must have been made in the first half of 1876. Clearly, Grandidier considered that consulting Crossley was worth a long special journey, a circumstance that makes it all the odder that in his 1892 listing of travels in Madagascar he did not see fit to include the English naturalist's 1874–5 and 1876–7 itineraries in his 1892 listing, despite the huge productivity of the former and the disastrous conclusion of the latter (see Tattersall 2022 for the sad details).

The very first mention of Crossley in any literature of which I am aware occurs in an article that Grandidier published in the February 1870 issue of the Paris-based *Revue et Magasin de Zoologie Pure et Appliquée*. Given that Grandidier was in far-away Madagascar at the time of its writing, that article, which bore the rather cumbersome title of "Description de quelques animaux nouveaux, découverts à Madagascar, en novembre 1869" cannot have been composed later than the end of 1869. Two of the five animals that Grandidier then described and named were a primate, *Chirogalus crossleyi* (Crossley's dwarf lemur, *Cheirogaleus crossleyi*), and a bird, *Bernieria crossleyi* (Crossley's babbler, *Mystacornis crossleyi*), that he specifically attributed to the collector for whom he named them, a "traveler who has been journeying through various parts of Madagascar for the *last two years*" (p. 50, emphasis added). This statement strongly suggests that Crossley, far from having first arrived as a collector in Madagascar in 1869 as I had supposed (Tattersall 2022), had in fact been conducting visits to Madagascar since late 1867. And indeed, the naturalist's initial return to Madagascar might well have been even earlier than that: in Volume VI of the *Histoire* Grandidier (1875, p. 2) notes that certain species were rare in collections back "in 1865 when [I] on the one hand, and Messieurs Lantz [Jean Auguste Lantz, Curator of the St Denis Museum of Natural History in Réunion], Pollen, Van Dam [and] Crossley, on the other, were undertaking journeys in the island of Madagascar." If Crossley was already collecting in Madagascar in 1865, it would have been a scant half-decade after his escape from slavery there. The balance of the mostly inferential evidence would seem to point in the direction of an early return; but while there are no evident grounds for doubting Grandidier's veracity or powers of recall, it is curious that there are currently no collections known to me that bear witness to any collecting activities by Crossley in Madagascar before 1869.

In stark contrast to earlier years, the zoological literature and natural history museum catalogues of the early 1870s abound with references to Crossley and the specimens he collected. The month after Grandidier's publication in the *Revue*, the Halifax entomologist Christopher Ward (1870a) described four new species of Madagascar butterflies. All were based on specimens that appear already to have been in the hands of the London agent William Cutter in December 1869 (see Tattersall 2022), and in July of 1870 Ward published seven more species (Ward 1870b). On both occasions Ward noted that the specimens had been "recently received" from Crossley, to whom he referred as "my collector in Madagascar," the only provenance he gave for any of them. Sharpe (1870, p. 384) elaborated on the situation a little more: "Ornithologists are greatly indebted to Mr C. Ward of Halifax, who, at his own expense, equipped Mr Crossley for this expedition [to Madagascar].” Ward is currently Crossley’s only known sponsor, either individual or institutional, and virtually all of the latter’s non-Ward specimens that I know of made their way into museums and the commercial market via commercial dealers, notably William Cutter and Edward Gerrard in London, Adolph Frank in Amsterdam, and Gustav Schneider in Basel. Indeed, according to Bowdler Sharpe (1871a, p. 602) it was Cutter “who trained [Crossley] in preparing specimens of natural history,” possibly at Ward’s behest. Ward continued to publish new Madagascar butterfly species until December 1873 (Ward 1873), at which time he abruptly ceased this activity and also likely terminated his support of Crossley.

During the four years between early 1870 and late 1873 Ward also published numerous new butterfly species from Africa, particularly from Cameroon, where Sharpe records he sent Crossley once the latter had concluded his 1870 collecting activities in Madagascar. According to Sharpe (1871a) the collector was also amassing bird specimens in Cameroon between November 30 of 1870 and February 25 of 1871 at a minimum, despite severe logistical difficulties posed by the locals’ unwillingness to exert themselves for the sake of natural history, “their profound laziness rendering it necessary to carry all his own collections himself from the mountains to the coast” (Sharpe 1871a: 603). Sharpe (1871a) rewarded Crossley’s efforts with the eponym *Turdus crossleyi* (*Geokichla crossleyi*: Crossley’s ground thrush), and Ward (1871) followed suit with “much pleasure,” by naming the new butterfly species *Godartia crossleyi* (*Euxanthe crossleyi*, Crossley’s forest queen) for him.

As early as June of 1870, Sharpe published the first of his series of papers (Sharpe 1870, 1871b, 1872, 1875, 1879) on the ornithology of Madagascar. Those careful studies were entirely based on bird specimens sent by Crossley to Cutter, many of which were then purchased for the British Museum’s collections. Sharpe’s contributions give us our best glimpses of the rich documentation that Crossley must have furnished with his specimens (and apparently also provided to Sharpe in person). Those glimpses include details of such ephemera as stomach contents, eye color, and behavioral habits, and even of some of the techniques of collection (in one case, by locals using blowpipes). After Sharpe’s first Madagascar paper there followed a stream of publications on Crossley-collected accessions to a variety of museums, by authors both from the UK and continental Europe; but announcements of new specimens began fading out after 1875, well before the collector’s death in 1877 (see Tattersall 2022 for the little that is known of that late period).

By the time of Grandidier’s 1876 visit to Halifax, Crossley and Grandidier had at least been aware of each other’s activities for several years, possibly for an entire decade. Which makes it all the more bizarre that, when alluding in the 1892 revision of Volume VI of the *Histoire* (p. I, footnote) to other naturalists who had recently visited Madagascar, Grandidier listed Wilhelm Peters, S. Roch, Edward Newton, Karl Klaus von der Decken, Auguste Vinson, Jean Auguste Lantz, Francois Pollen, and Casparus Van Dam, but did not mention Alfred Crossley – even though the English collector’s name appears several times in the pages that follow. It might be relevant that, apart from Van Dam, the explorers Grandidier listed were all from the upper echelons of society, whereas the impoverished Crossley was solidly working-class. And while Van Dam’s origins might not have been vastly higher up the social scale than the lone operator Crossley’s were, his social acceptability may have been enhanced by his close association with the wealthy Pollen. It is also possible that, as a result of his early experience, Crossley possessed a tendency to “go native” in the field, much as his fellow collector Jules Prosper Goudot had done earlier and to the great disapproval of his straitlaced contemporaries (Andriamialisoa and Langrand 2022). For numerous reasons, then, the exact nature of the relationship between the affluent Grandidier and the humble Crossley remains obscure. But we do know a relationship existed, raising further questions regarding Crossley’s relative invisibility.

ANTSIHANAKA

As noted, in February 1870 Grandidier published descriptions of five new animals (one primate, two bats, one tenrec and one bird) that had been “discovered in Madagascar in November 1869” (Grandidier 1870). In that publication Grandidier stated specifically that the primate (*Cheirogaleus crossleyi*, from the “forêts est d’Antsianak”) and the bird (*Bernieria crossleyi*, without provenance), had both been collected by Crossley; the others he had presumably obtained himself. By “est d’Antsianak,” Grandidier was referring to the mountainous and densely forested escarpment to the east and south of Lake Alaotra, and we know independently from Bowdler Sharpe (1870), whose information came directly from Crossley, that in this same period the Englishman was actively collecting at two sites in that same eastern Antsihanaka region: Nosy Vola (“pronounced “Voula”) and Saralalan. Both of these sites lay “southeast of Lake Alout” (Sharpe 1870, p. 385) and were almost certainly somewhere in the vicinity of today’s Zahamena National Park (Andriamialisoa and Langrand 2022). Saralalan apparently lay “about seven or eight miles to the eastward of Nossi Vola” (Sharpe 1870, p. 385). Goodman et al. (2006) very plausibly identify Crossley’s Nosy Vola with the modern village of Nosivola that lies some 5 km north of the small town of Manakambahiny-Est, and in close proximity to the western boundary of the Zahamena reserve (Figure 2). It is unknown exactly how much time Crossley spent in the Antsihanaka region in 1869; but Sharpe quotes collecting dates indicating that he was at Nosy Vola between October 19 and 28, and at Saralalan not only at various times between November 10 and 20 of 1869, but also on January 28 and February 1 of 1870 (Sharpe 1870, 1871b). He also records that Crossley was at Nosy Vola on November 10, 12 and 13 (possibly servicing traps at both sites simultaneously), thereby not only confirming that the two localities were within an easy walk of each other, but also closely constraining Crossley’s whereabouts from mid-October of 1869 to early February of 1870.

Based on what I then knew of the French geographer’s travels, I suggested previously (Tattersall 2022) that Grandidier must have obtained his November 1869 specimens directly from their collector, and in the field somewhere close to Zahamena, maybe in the town of Ambatondrazaka at the southeastern end of the Alaotra basin. This would be consistent with the species collected; and if the timing were right, the necessary direct encounter between the two naturalists would not have been difficult to contrive, no matter how remote its exact location: the local people for miles around would have known exactly where the two *vazaha* (foreigners) were. And the timing was almost right, because Grandidier’s own handwritten notebooks record that, between October 12 and November 3 of 1869, the French naturalist undertook a journey from Antananarivo to Lake Alaotra and back (“Voyage de

Tananarive au lac d'Antsianak," MNHN General Library Ms 3261, Vols X and XI). The purposes of this journey appear to have been purely geographic; the French explorer's very detailed (almost minute-by-minute) private notebooks do not mention any collecting activities.

However, as tempting as it might be to conclude that the two naturalists must have met at this time, the notion is not borne out by Grandidier's minutely detailed contemporaneous account. Recording his stopping points and geographic observations to the minute (though rarely noting his direction of travel), Grandidier makes it clear that he proceeded east from Antananarivo to some point in the vicinity of today's Moramanga, and then turned north up the Ankay plain to the Lake Alaotra basin. On Day 9 of his journey (October 20) he arrived in the vicinity of the Hova (central government) fort at Ambatondrazaka, lying at the southeastern margin of the extensive wetlands and mudflats that surround the southern and western parts of the lake (Figure 2). The next day he continued up the eastern side of the marshes to some point near Andreba where, then as now, open water commenced. Andreba would have been an ideal jumping-off point for a visit to Crossley's sites to the east of the lake (the only modern road to the region begins there, and as the crow flies Nosivola is less than 20 km. distant along it); but instead, after exploring an island near the lake's eastern shore, Grandidier traveled from Andreba around the southern tip of the lake and headed west, walking across seasonally dry mudflats to reach a place he called Amboitse-Tsara. He spent the night somewhere in its vicinity, possibly close to today's Ambatomainty.

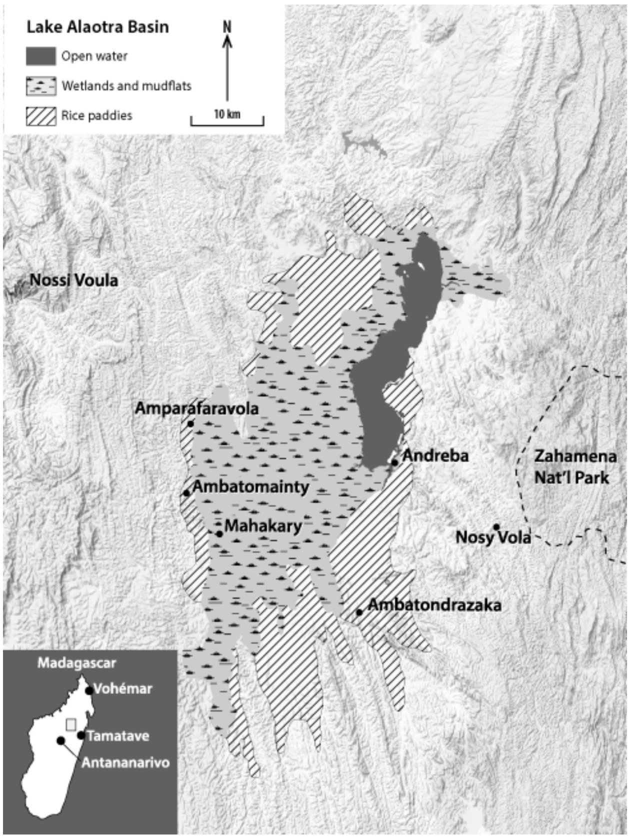

Figure 2. Map of the Lake Alaotra Basin ("Pays d'Antsianak"), showing the presumed location of Alfred Crossley's Nosy Vola collecting site (his other site of Saralalan lay a short distance to the east, possibly within the boundaries of today's Zahamena National Park). Also shown are the places visited by Alfred Grandidier during his Antsihanaka voyage that are identifiable today. Arriving from the south, the explorer proceeded from Ambatondrazaka up the eastern side of the lake basin to Andreba where he investigated a nearby island by canoe. He then rounded the southern tip of the lake and crossed an area of mudflats to reach the western edge of the basin. At that point he turned north, following the base of the hills to the peak of Nossi Voula. Thence he traveled south again to Amparafaravoula and on to Mahakary by canoe, thence to Ambatondrazaka and on to Antananarivo. The basin in which Lake Alaotra lies is surrounded by hills, and open water is restricted today to its northeastern part. To the west and south lies a vast area of marsh and mudflats crossed by navigable waterways. In many peripheral areas wetlands have been replaced by rice paddies, the approximate extent of which is depicted as on the IGN 1:500,000 map of 1964; during the mid-nineteenth century cultivated areas would have been significantly smaller. Map by Jennifer Steffey.

The next day Grandidier and his retinue walked broadly west, through countryside depopulated by Sakalava tribal raids, toward the rugged terrain that marks the western edge of the Alaotra basin. On October 24 he turned north, following the base of the western hills. At 9:19 am he spotted two peaks ahead, both surmounted by forest. A village nestled at the foot of the higher and more distant one. Amidst numerous erasures in his notebook, Grandidier noted that the larger hill and the village bore the same name: "Nossi Voula." At 9:31 he began his ascent of this peak, reaching its summit at 9:55. By 10:35 he was back on the plain, where he and his porters took a break until 2 pm. After restarting in a southerly direction, by 4:30 pm he and his companions were already in sight of "Amparafaravoula" (Amparafaravola), the lake basin's second largest settlement, lying on its western edge more or less directly across from Andreba. We can identify this place with confidence, not only because it retains the same name today but because Grandidier featured it ("fort Hova dans l' O. du lac") in the list of important Antsihanaka localities he compiled for the *Géographie* volume of the *Histoire* (Vol. 1, p. 140). Grandidier's Nossi Voula must thus have been located within a 3-hour brisk walk (Grandidier typically walked briskly, favoring 120 paces/minute wherever possible) of Amparafaravola village. The next day the naturalist continued south by pirogue, reaching the islet of Mahakary after four hours. From there he could still see the summit of Nosy Voula behind him, at a compass bearing of 328°. That is very close to the bearing to Amparafaravola itself from the islet, making it virtually certain that Nossi Voula was the higher of the twin peaks that appear on the Institut Géographique National (IGN) 1:500,000 map (Tamatave sheet 6) some 20 km. to the northwest of the town, just beyond Ambohimanga village (Figure 2). From Mahakary, Grandidier proceeded by canoe to the Hova fort at Ambatondrazaka, paying a courtesy visit to the commandant and staying two nights.

Interestingly, it was after Grandidier had returned to the fort, following a day-long foray on October 27, that he made the only reference to Crossley that one finds in his entire journal of the Antsihanaka journey. In a brief remark on the north-south extent of the rainforests that lay not far to the east of Ambatondrazaka, he noted that the land to the south of 'Vouhima" was mountainous and forested, but that the area to its north was "nu et sterile" (thereby confirming, significantly, that references to "Vohima/Vouhima" made at the time were not necessarily to the eponymous port town, but to the entire former province that had been administered from it). Since Grandidier had never visited northern Madagascar, he must have received this environmental information from an informant. That informant was most likely Crossley, because Grandidier went on to write that "on me parle d'un dépôt de coquilles fossiles abondants peu au nord et aussi de mines de charbon (renseignements Quinet à Crossley)."

So, when and where had Grandidier obtained the information that he attributed to Crossley? And why should Grandidier have found himself musing about the north of Madagascar, which he had never seen, in the middle of updating what was otherwise a pretty straightforward account of his current journey? His note certainly reads as if Quinet had informed Crossley (whose journey earlier in the year had begun in Vohémar) about the fossil shells, and that the latter had then relayed the information to Grandidier. But how? If the exchange did not occur in Antsihanaka, it could only have happened in person if Crossley had indeed been to Vohémar before 1869, and the two naturalists had subsequently met prior to that year. Conceivably, Grandidier had received Crossley's report from an intermediary; but if so, it is very odd that Grandidier should not have mentioned the fact while naming everyone else. Is it just possible to imagine that Crossley and Grandidier actually met at the Ambatondrazaka fort on October 27 and traded information (and possibly the specimens that Grandidier published early the next year)? And that Grandidier had simply neglected to mention the fact in his journal? Like much else in this story, that speculation stretches credulity; and in the very unlikely case that it is accurate, why such an egregious lapse in a hugely detailed personal record? We currently have no way of resolving any of these uncertainties, although on balance the little we know does seem to support the idea that Crossley had worked in Madagascar before 1869. All we can be sure about is that, having made this cryptic reference to his fellow Antsihanaka voyager, Grandidier did not linger in Antsihanaka. After two nights at Ambatondrazaka he headed south and west again, retracing his steps to Antananarivo and arriving there on November 3, Day 23 of his journey.

It may boggle the imagination that both Grandidier and Crossley, shortly to be linked forever by zoological nomenclature, should have independently and unwittingly found themselves at two different sites, both with the unusual name of Nosy Vola ("treasure island," even though neither was an island), and both in the Alaotra Basin, on the very same date: October 24, 1869. And despite the strained relations then existing between the English and the French in Madagascar, and the uncertainties just raised, there is no obvious professional reason why Grandidier should have deliberately omitted any mention of contact with Crossley from his private notebooks (which also make it pretty clear that he had not had the time to divert to from Andreba to Nosy Vola). As for the "Nossi Voula" reference, it is very clear from Grandidier's journal entries that by October 24 he was already on the western side of the lake, while both Bowdler Sharpe's account, and Grandidier's insistence on the "est d'Antsihanaka" origin of his *Cheirogalus crossleyi*, make it virtually certain that on this date Crossley was at his Nosy Vola, or just possibly Saralalan, and that both of those sites were on the eastern side of the Alaotra basin and in the vicinity of today's Zahamena National Park (Goodman et al. 2006, Andriamialisoa and Langrand 2022). That latter geographical location is also consistent with the mammal and bird species Crossley was collecting at the time at Nosy Vola and Saralalan – although Grandidier did note, in his journal entry for October 31, 1869, that very similar forest to that of the east also existed "à l'O[uest] et à peu de distance d'Amparafaravoula," so perhaps the case cannot be considered entirely closed on grounds of general habitat. And of course, if Crossley and Grandidier did not meet on October 24, 1869, then we can more readily accept Grandidier's (1870) declaration that the holotype of Crossley's Dwarf Lemur was indeed collected in November of that year, as clearly stated in the title of the paper describing it. Sadly, the specimen itself cannot help because there is no evidence that it ever reached the MNHN in Paris – supporting the report that all the materials described by Grandidier in early 1870 were destroyed together in that warehouse fire in Réunion.

Still, if the English and French naturalists did not meet somewhere in Antsihanaka, how did Grandidier obtain his Crossley specimens within the very short window of time available for him to write his manuscript and ship it to France for publication? Most likely, perhaps, an intermediary in Antananarivo was involved – and Crossley was, after all, in the habit of disposing of his materials through third parties. Grandidier could then have purchased his Crossley types from the naturalist's representative after his return to the capital from Antsihanaka in early November (hence "discovering" them that month). Or maybe they were acquired toward the end of November, or even in early December, because even if the specimens had been collected in Antsihanaka right at the beginning of November, it is unlikely they could have been in Antananarivo much before November 8, when the restless Grandidier departed on an excursion to the Andringitra Massif. Finally, it is just possible that at some time in November of 1869 Crossley himself came briefly to Antananarivo to obtain supplies or to ship out specimens, and encountered Grandidier who bid on the two specimens before they could be sent to Cutter. Still, the probability that Crossley was very busily collecting at Nosy Vola and Saralalan from mid-October of 1869 through early February of 1870 argues quite strongly against a time-consuming visit to Antananarivo, as possibly also does the absence of any mention of Crossley in the records of the fairly numerous English missionaries in Antananarivo at the time (although, apart from the appearance of his name in a list of collectors in Madagascar quoted in the *Antananarivo Annual* from the February 3, 1876 issue of *Nature*, there are admittedly no later mentions either, even though it is virtually certain that Crossley subsequently visited Antananarivo more than once). All in all, if we can take the title of Grandidier's paper literally, an intermediary must have been involved in the transfer of the specimens.

AN ENDURING ENIGMA

So, did Crossley and Grandidier ever actually meet before the latter's visit to Halifax in 1876? We know they must have been involved in some kind of transaction over the two holotypes in 1869, but it is not clear that it required personal contact. In November of 1869 Grandidier was within several months of ending his last visit to Madagascar, implying that, unless Crossley really did start working in Madagascar in 1865 or 1867 (as Grandidier claimed/suggested in 1892 and 1870, respectively, and seems plausibly to have been the case even in the absence of direct evidence), the opportunities for a personal encounter in Madagascar would have been few or nonexistent. Up until the time of Grandidier's trip to Antsihanaka, Crossley had been fully occupied by his collecting activities in the north and east of the island, and as far as we know he had yet to visit Antananarivo on this occasion (Tattersall 2022). For his part, Grandidier is known to have left the island for the last time in August 1870, departing from Tamatave. Previously (Tattersall 2022) I quoted a departure date for Grandidier of July 26, 1870, citing a contemporary newspaper report; but one of Grandidier's handwritten notebooks contains a copy of a letter to the British Consul datelined "le 10 Août 1870. Tamatave," so his long-anticipated leaving had evidently been delayed by the outbreak of the Franco-Prussian War in mid-July, consistent with Faure et al's (2019) report of a "fin août" departure. According to a press report (see Tattersall 2022), Crossley was "missing" between

May and mid-July of 1870; but he had reappeared by July 16, so that if he had promptly returned to his probable home base of Tamatave he would have overlapped there with Grandidier by up to six weeks. Despite Crossley's tendency to invisibility, the fact that Grandidier had just named two vertebrate species after him would surely make it rather improbable that, both as members of a tiny expatriate community, and as possible acquaintances of long standing, the two naturalists would not have interacted in some way.

In answering questions of this kind it would help to know a little more about the personal and social relationships that existed between the English and French naturalists. Their nations were rivals for political favor in Madagascar in the decades following the death of Queen Ranavalona I in 1861, and the resulting spirit of mutual suspicion might naturally enough have served as a barrier. Nonetheless, given that Grandidier named two species for Crossley, and later visited him in Halifax to obtain information, the likelihood must be that some form of relationship, or at least some degree of mutual respect, existed between them. Still, evidence for the nature of the two men's association remains exceedingly thin. Crossley contrived to leave behind mystifyingly few documentary traces, so for his part this seems inevitable. But in addition to his voluminous publications, Grandidier (and his son Guillaume) left a substantial Madagascar archive that is now in the Library of the MNHN in Paris, raising the hope that the French geographer might at least informally have recorded more about the English naturalist. Sadly, though, the elder Grandidier's notebooks disappoint in this respect, and his archive preserves very little correspondence from the time of his Madagascar explorations. Indeed, aside from the single journal entry quoted above, I have been able to locate within the Grandidier archives only two other documents, both handwritten, that mention Crossley's name.

One of those items, dated 1874, is a torn scrap of paper that merely bears Crossley's surname and the title of a paper in which the English entomologist William Chapman Hewitson (1874) described a new genus of Madagascar butterfly from a Crossley specimen. This bare reference to Hewitson and Crossley must almost certainly relate in some way to the second document, which is an undated list of names and addresses of naturalists with whom Grandidier presumably corresponded. In order of listing, those naturalists are: Otto Staudinger, the German natural history dealer and entomologist; Christopher Ward, Crossley's Halifax sponsor; Crossley himself; Henley Grose-Smith, an English lepidopterist who owned the butterfly that was collected by Crossley and described by Hewitson; Robert McLachlan, a British butterfly expert and first editor of the *Entomologist's Monthly Magazine* in which Ward and Hewitson both published Crossley specimens; Hewitson himself; Johannes Keulemans, a well-known Dutch artist based in London and illustrator of several volumes of Grandidier's *Histoire de Madagascar*; and Richard Bowdler Sharpe, the BMNH ornithologist. Madagascar (or Crossley specimens from the island, or even Crossley himself) might supply a fairly weak connection among all or most of these individuals; but the exact reasons for which Grandidier compiled the list remain tantalizingly obscure.

In retrospect, we can see both Alfred Crossley and Alfred Grandidier as giants of early natural history collecting in Madagascar. Their travels around the island may have overlapped by as much as half a decade; and they clearly did not consider themselves outright rivals, since one of them evidently supplied the other with important specimens and precious information. So why was there so little apparent (or at least recorded) interaction between them, even when Grandidier's travels brought him so close to Crossley in the remote Alaotra Basin, where they were likely the only *vazaha* for many miles around? And, perhaps more significantly, why did Grandidier, an industrious note-taker, do so little to record any interactions between them that there might have been? Grandidier was reportedly fluent in English, while Crossley is said to have been both kind and self-effacing (Anon. 1877), and on an individual level he seems hardly to have been the kind of person that anyone interested in the natural history of Madagascar would have wished to avoid (with the likely exception of the rival collector Josef-Peter Audebert: see Tattersall 2022). Indeed, while entirely lacking any scientific pretensions Crossley was clearly a keen and retentive observer, and he almost certainly possessed extensive knowledge of great interest to Grandidier even before he had collected *Propithecus coronatus* in the northwest. Nonetheless, self-effacement seems to have triumphed.

One can only suppose that the reasons for Crossley's almost complete invisibility to other Madagascar travelers lay deeply embedded in the same class barriers as those that also seem to have prevented him from interacting in the nearby British colony of Mauritius with his fellow countryman and Madagascar explorer Sir Edward Newton. The latter had observed and collected birds in Madagascar on two occasions during the early 1860s (Roch and Newton 1862, 1863; Newton 1863a,b), and he was resident in Mauritius as Colonial Secretary from 1859 to 1877, during which time Crossley visited the colony at least twice (Tattersall 2022). Birds, natural history in general, and an acquaintanceship with Madagascar would have given Crossley and Newton an enormous amount in common intellectually; and a letter dated August 3 1873 from Crossley to the administrator's brother, the Cambridge ornithologist Alfred Newton, while simply an acknowledgment of payment (presumably for bird specimens), does bear witness to a connection of some kind, however indirect. Once again, the lack of any evidence that the two English Madagascar explorers ever met, even if only formally by crossing paths at a meeting of the Mauritius Institute, appears to be yet another indictment of the stultifying class system within which they (and also, it seems, Grandidier) were imprisoned.

Finally, it should be noted that the mid-nineteenth century was the period during which scientific knowledge of the biogeography of Madagascar was beginning to become organized. Both Crossley and Grandidier were instrumental in this nascent process, the latter, for instance, producing (with some help from Crossley) the first comprehensive distribution maps of endemic vertebrate species in Madagascar of the kind that still guide conservation efforts today. As Crossley's movements around the island gradually come into focus they tend to suggest, in combination with other evidence, that from a biogeographic point of view Madagascar a century and a half ago was in many respects remarkably similar to the way it is now. This suggests a substantial resiliency in Madagascar's ecosystems: a resiliency that must surely encourage those devoted to their conservation in the face of twenty-first century threats.

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The art of brickmaking in Madagascar: A lifeline and its challenges

Sam Feibel [1]

Correspondence:
PO Box 162
Canton Center, CT 06019
USA
Email: sam.feibel@outlook.com

ABSTRACT
Artisanal brick production provides a crucial livelihood for many families in Madagascar. This essay explores the historical context, socio-economic drivers, and potential environmental impacts of this widespread practice. It challenges the simplistic narrative that associates brickmaking solely with environmental degradation and highlights the need for more nuanced research to understand its drivers and long-term effects.

RÉSUMÉ
La production artisanale de briques constitue un moyen de subsistance essentiel pour de nombreuses familles à Madagascar. Cet essai explore le contexte historique, les moteurs socio-économiques et les impacts environnementaux potentiels de cette pratique. Il remet en question le récit simpliste qui associe la fabrication de briques uniquement à la dégradation environnementale et souligne la nécessité de recherches plus nuancées pour comprendre ses moteurs et ses effets à long terme.

INTRODUCTION
Since the British missionary James Cameron introduced open air clamp kiln technology to Madagascar in 1826, fired bricks have become one of the most popular building materials in the country (Leonardi 2003). Artisanal brick production occurs in the Highlands and in coastal areas, where differences in geology result in mineralogically distinct bricks. In the Central Highlands, thick, clay-rich lateritic soils offer an abundant source of raw material. As a result, brick production sites are widespread across the Highlands landscape, though their greatest density is near villages and urban areas (Grifa et al. 2017).

This essay explores artisanal brick production in Madagascar and the transformation of the landscape it entails (Figure 1). The economic, sociocultural, and environmental dimensions of this widespread, informal industry are poorly understood, though some have speculated on its drivers and impacts. Drawing from field research at rural and urban brick production sites in Madagascar, as well as laboratory analysis of raw materials and fired bricks, Grifa et al. (2017, 2021) offer a bleak assessment: "[Brick production] has remained unchanged for more than 200 years and even if new social and economic opportunities arose, this unvirtuous system slowly (but inexorably) contributed to the impoverishment of important energy sources and, above all, of natural resources (Grifa 2021: 1)."

However, the pervasive narrative about Madagascar, which assumes that population growth and poverty drive a downward spiral of forest clearance, environmental degradation, and ever deepening poverty, has drawn criticism. Notably, Scales (2011: 501) observes "[research] has…tended to lump Malagasy farmers together into a single category, ignoring the biophysical, political, economic and cultural diversity…[with] few attempts to understand the underlying factors driving land use." Given the current knowledge gap in Madagascar, it is premature to dismiss artisanal brick production as unsustainable in all contexts. Through personal observations and existing literature from Madagascar and elsewhere, I explore this informal yet vital industry and suggest areas in need of further research.

HISTORICAL AND GEOGRAPHICAL TRENDS
Demand for construction has made artisanal brick production an important income-generating activity in many Malagasy communities. As a Peace Corps volunteer (2017–2019), I lived near several brick production sites in the commune of Imerintsiatosika, a large, developing market center in the Central Highlands. During that time, I witnessed the rapid expansion of brick infrastructure in the form of new homes, tall, long walls enclosing property boundaries, and other structures. To meet demand, brick producers excavated an increasing number of pits within rice paddies and along the edges of valley bottoms (Figure 1). I returned briefly to Imerintsiatosika in August 2023 and the continued expansion of brick infrastructure and sediment extraction sites was evident. New neighborhoods of brick houses surrounded by brick walls stood on what was empty land on the outskirts of town just a few years prior.

My personal observations aside, the extent, rate of growth, and economic importance of artisanal brick production in Madagascar are not known. In Greater Antananarivo, Earth observation data show that nearly 14% of total urban land use (2.5% of total land area) is devoted to brick extraction (Dupuy et al. 2020). It is

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Figure 1. Brick kilns firing. The smoke of burning rice husks fills the air. (photo Sam Feibel)

unclear, however, how much production occurs on agricultural land, which constitutes 44% of total land area. Reportedly, farmers in Antananarivo's agricultural floodplains often consider brickmaking the first step towards radical land use change, with some plots ultimately used for urban construction when the soil is exhausted (Aubry et al. 2012).

Outside Madagascar, researchers have used remote sensing and machine learning to identify brick production sites over large areas with high precision and accuracy (Lee et al. 2021). These techniques applied to historical imagery in Madagascar would provide insight into the growth patterns and environmental footprint of the industry and could be a basis for estimates of the industry's economic value. Interviews with farmers and brickmakers, covering a range of brick production sites, would complement remote sensing analysis, adding nuance and context to observed trends.

DRIVERS OF BRICK PRODUCTION

Artisanal brickmaking involves physically demanding, long hours. In Nepal's Kathmandu Valley, musculoskeletal injuries were found among brickmakers, including children, as were respiratory issues linked to smoke and fine particulate matter (Joshi et al. 2013, Sanjel et al. 2017). In Madagascar, I often observed small children involved in various stages of brick production—particularly when large families worked together to stack sun-dried bricks into kilns for firing. The health impacts of artisanal brick production have not been studied in Madagascar, but the laborious nature of the industry begs the question of why smallholders would choose to remove soil at great physical cost, rather than grow food in it. For this question, Bangladesh serves as a potentially instructive case study.

Urbanization in Bangladesh has driven high demand for bricks, placing a premium on soil from agricultural fields. Some farmers in the Dhaka and Jessore districts remarked that due to the excavation of soil for bricks on adjacent farm plots, their land was effectively elevated in relation to the surrounding land, decreasing their soil's capacity to retain water and fertilizer and pushing them to excavate their soil for brick production as well (Biswas et al. 2018). Other factors that drove farmers to sell soil included higher profits and faster cash returns compared to agriculture, low barriers to entry, and the ability to retain ownership of the land and perhaps grow crops there again in the future. Declining soil productivity and uncertainty in the profitability of rice cultivation due to fluctuating market prices, fertilizer availability, and climatic events also pushed farmers to sell soil (Biswas et al. 2018).

The factors driving farmers to produce bricks in Madagascar are not well understood. In the Central Highlands, bricks are made between the months of June and November, when rain won't destroy air-drying bricks or extinguish open-air kilns. During the dry season, valley bottom land cultivated for rice is left fallow (and available for brick production). This seasonality allows for livelihood diversification when farmers are not laboring in rice fields. Sun-drying molded bricks, stacking them into a furnace, and firing them takes on average twenty days to one month (Grifa et al. 2017). Motivated producers can fire bricks more than once during the dry season. One brickmaker I spoke with in August 2017 reported having worked with her family starting at sunrise six days a week for the two months prior, producing 100,000 bricks.

Because the simple clamp kilns used in Madagascar are not permanent structures, producers can fire bricks at the sites where they extract sediment. This capacity for opportunism, coupled with the abundance of clay in many Highlands soils, means that brickmakers can turn sediment into a commodity across much of the landscape. The kilns consist of stacked bricks layered with fuel in an open-air environment and are energy-inefficient due to high heat loss (Grifa et al. 2017). In many countries, clamp kilns have been replaced with more thermally efficient technologies, but in India, for example, the former are still used to produce an estimated 20% of the 247 billion bricks made annually. Despite their relatively small contribution to total brick output in India, an estimated 70% of all kilns in the country are clamp kilns (Eil et al. 2020), testimony to the accessibility of this kiln technology to producers.

The most popular fuel used to fire bricks in Madagascar's Highlands is rice husk due to its widespread availability. Unlike wood, rice husk is an abundant, relatively cheap recycled agricultural byproduct with no major alternative uses (Grifa et al. 2021). In Imerintsiatosika, I was told that the price of rice husk varies slightly each year and is available at no cost some years. This may depend on the year's rice harvest, the demand for fuel to fire bricks, or other factors. The accessibility of rice husk—combined with a producer's ability to fire bricks where sediment is found—allows for opportunistic, seasonal brickmaking.

BRICK PRODUCTION'S IMPACT ON FOOD SECURITY AND THE ENVIRONMENT

Though no country-wide data are available, brick production has been labeled a major source of greenhouse gas emissions in Madagascar, with each kiln requiring around 10 tons of fuel (Grifa et al. 2021). Choice of fuel—rice husk, wood, or peat—impacts the environmental and economic sustainability of firing. In some regions of Madagascar, hardwood harvesting for brick kiln fuel may drive unsustainable deforestation in the same manner as charcoal production for cooking fuel. In August 2023, I met with brickmakers using wood from local forests to fire bricks outside the Southwestern city of Toliara. In the Highlands—on the other hand—where rice paddies abound, rice husks are an easily accessible fuel source.

When bricks are fired, the burning of organic matter that occurs naturally in clay deposits is another source of CO2 emissions (Grifa et al. 2017). The amount of organic matter in sediment deposits may depend on location, however, and whether that sediment comes from agricultural valley bottoms or grassy hillslopes. An estimated 79% of Madagascar's soils are oxisols, characterized by very low organic matter content (Paul et al. 2022).

While brick production and agriculture are seasonally complementary livelihood activities in Madagascar's Highlands, brick production may compete with agriculture when brickmakers permanently remove sediment from productive valley bottoms. In Greater Antananarivo, brickmaking is expanding rapidly at the expense of rice paddies, with soil excavation reportedly disrupting agricultural water management systems (Dupuy et al. 2020). However, farmers who rent their paddies to brickmakers have often been observed to repurpose the excavation pits later for agriculture (Grifa et al. 2017). In the floodplains of Antananarivo, a common strategy on small farm plots is the "bricks, rice, duck, fishing" system, in which smallholders engage in all four activities on the same plot over the course of a year. Aubry et al. (2012) suggest that this system of seasonal livelihood diversification becomes unsustainable after a few years, with soil becoming unsuitable for both cultivation and brick production, though evidence for this trend is localized and anecdotal.

The excavation of soil for brick production may not always diminish agricultural production, at least in the short term. Brickmakers do not exclusively excavate rice paddy soil. In the Highlands, they also dig laterally into clay-rich hillslopes, thereby expanding valley bottoms and creating more irrigable land for paddy rice and other crops. These hillslopes contain nutrient-poor, compacted soils and are often marginal agricultural land that is unutilized, grazed by cattle, or planted with hardy crops like cassava prior to their transformation for brickmaking.

In Imerintsiatosika, I often observed brickmakers planting rice, vegetables, and bananas within active excavation pits cut into hillsides. When I returned in August 2023, I noticed that an area where I used to play soccer at the edge of a hillslope had been transformed into a pit so deep that groundwater filled the bottom. I asked one of the men digging into the towering wall of sediment what would become of the hole once brickmaking eventually stopped at the site, and he replied "atao tanim-bary avy eo [it will be made into a rice paddy later]." I had no reason to doubt him, since the rice paddy just a few meters downhill from the new pit had itself been a brick production pit when I'd been there just a few years earlier. Analysis of satellite imagery and ground truthing could examine how such pits are seasonally cultivated, and how long they remain viable for alternating brick production and agriculture.

One study of smallholder livelihood adaptation in Zimbabwe —which occupies the same latitudinal range as Madagascar's Highlands and experiences similarly seasonal rainfall—highlights the complexities of the connection between artisanal brick production and food security. There, Pasipangodya and Mwenye (2020) argue that smallholders engage in seasonal non-farm activities such as brick production to improve food security through diversifying income streams. The study is a rare case that views artisanal brick production largely in a positive light, with diversification improving food security in the face of environmental risks such as increasing climate variability and water scarcity.

BRICK LANDSCAPES

> "Degradation occurs when a natural habitat loses value of every kind…Transformation, in contrast, involves a change in the currency by which a natural habitat is valued."
> — (Richard and O'Connor 1997: 407).

Anthropologists have long drawn attention to the rationality of smallholder livelihood adaptation strategies, exposing misplaced assumptions that unequivocally link land use choices (swidden agriculture, for example) with environmental degradation (Scott 1976, Dove 1983). In Madagascar, Kull (2000) argues that rationality, not poverty, drives land use decisions, noting: "Rarely would *tantsaha* (agriculturalists) continue practices clearly detrimental to their own livelihoods!" (Kull 2000: 434). Like the clearing of forest for agriculture, brick production should be seen as the outcome of a "change in currency" that Richard and O'Connor (1997) describe. Brickmakers in Madagascar adapt to highly localized conditions, where, among other factors not yet documented, access to markets, sediment, and fuel all play a role in the environmental impact and economic viability of production.

The ecological sustainability of many agricultural landscapes in Madagascar is uncertain. Many of Madagascar's natural valley bottoms were transformed for agriculture centuries ago. This complicates efforts to understand the geomorphological and ecological impacts of sediment extraction for brickmaking, which have not been studied. In some cases, it has surely led to reduced agricultural productivity and harmful ecological impacts. In others, however, it may represent a more sustainable transformation of the landscape.

Today, Madagascar's transformed, "biocultural" landscapes harbor important agroecological diversity (Carrière et al. 2022), and what happens to them over the coming decades will determine the sustainability of human and nonhuman life across much of Madagascar far into the future.

CONCLUSION

Artisanal brick production is a vital livelihood activity for many Malagasy families. It also poses challenges that need to be addressed through targeted research. Interviews with brick producers would help build a basic understanding of the informal industry, illuminating how brickmaking compares to other income-generating activities, and how that may vary across geographic regions.

To understand the potential environmental impacts of artisanal brick production, future research should recognize the importance of context. Studies should account for differences in fuel availability and landscape characteristics between sites and should examine change in the extent of brick production through space and time. In addition to analyzing the spatial relationship between brick production and agriculture on the landscape, researchers should seek to understand brickmakers' perspectives on the economic, social, cultural, and environmental dimensions of their livelihood. This will give insight into the drivers of brick production as a livelihood strategy and inform assessments of Madagascar's construction industry as demand for housing continues to grow.

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Madagascar's proposed domestic rosewood trade undermines species protection and exposes fatal flaws in the CITES regime

Mark W. Roberts[1], Derek Schuurman[2], Porter P. Lowry II[3,4], Lucienne Wilmé[5] and Patrick O. Waeber[6,7]

Correspondence:
Mark W. Roberts
Eco Policy Advisors, 122 Kirkland Drive
Stow, Massachusetts 01775, USA
Email: mark@ecopolicyadvisors.com

Patrick O. Waeber
Ecosystems Management, ETH Zürich
Universitätstrasse 16
8092 Zurich, Switzerland
Email: powaeber@gmail.com

ABSTRACT
Madagascar's proposal to expand its domestic trade in rosewood by allowing the use of logs from its "official" stockpiles, which have been embargoed, undermines international conservation efforts and exposes critical weaknesses in the CITES regime. Despite the listing of all Malagasy rosewood species on CITES Appendix II and the implementation of a trade moratorium, illegal exports of rosewood persist, driven by criminal syndicates exploiting gaps in enforcement and forest governance. The proposal to remove 30,000 logs from CITES jurisdiction, purportedly for domestic use, lacks adequate safeguards to prevent their diversion into international markets and trade. This move threatens to set a dangerous precedent for other countries, potentially facilitating illegal trade in other rare or endangered species. Immediate, stringent oversight and effective enforcement mechanisms are essential to mitigate these risks and uphold global conservation objectives.

RÉSUMÉ
La proposition de Madagascar d'élargir son commerce intérieur de bois de rose en autorisant l'utilisation des grumes provenant de ses stocks « officiels », qui avaient été placés sous embargo, compromet les efforts internationaux de conservation et révèle des faiblesses critiques dans le régime de la CITES. Malgré l'inscription de toutes les espèces de bois de rose malgache à l'Annexe II de la CITES et la mise en place d'un moratoire sur leur commerce, les exportations illégales de bois de rose persistent, alimentées par des réseaux criminels exploitant les failles de l'application des lois et de la gouvernance forestière. La proposition de retirer 30 000 grumes de la juridiction de la CITES, soi-disant pour un usage domestique, ne présente pas les garanties suffisantes pour empêcher leur détournement vers les marchés internationaux illégaux. Cette mesure risque de créer un précédent pour d'autres pays, en facilitant potentiellement le commerce illégal d'autres espèces rares ou en danger. Une surveillance immédiate et rigoureuse, accompagnée de mécanismes d'application efficaces sont essentiels pour atténuer ces risques et maintenir les objectifs mondiaux de conservation.

CONTEXT
Rosewood is one of the most sought-after commodities in the international wildlife and timber trade. The illegal sale in this valuable resource yields more revenue than products derived from elephants, rhinos, and big cats combined (UNODC 2020). Illegal commerce in animals, plants, and their parts generates US$71–171 billion annually, making it almost as lucrative as trafficking drugs, arms, and people, and usually involves the same criminal syndicates (Anagnostou and Doberstein 2022). Vigilant and unscrupulous criminals take advantage of gaps in CITES policy, capacity, and enforcement—as well as in national implementation, enforcement infrastructure, and legal systems—to trade rare and

1 Eco Policy Advisors, Stow, MA, USA
2 London
3 Missouri Botanical Garden, 4344 Shaw Blvd, St. Louis, Missouri 63110-2291, USA
4 Institut de Systématique, Évolution, et Biodiversité (ISYEB), Muséum national d'Histoire naturelle/Sorbonne Universités/Centre national de la Recherche scientifique/École Pratique des Hautes Études, 75005 Paris
5 Missouri Botanical Garden Madagascar Research and Conservation program BP 3391 Antananarivo 101
6 Forest Landscape Governance, HAFL, Bern University of Applied Sciences, Länggasse 85, 3052 Zollikofen, Switzerland
7 Ecosystems Management, ETH Zürich, Universitätstrasse 16, 8092 Zurich, Switzerland

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threatened species with little risk of prosecution or confiscation of the seized material (Anagnostou and Doberstein 2022). Left uncontrolled, such trade is likely to drive many species to extinction.

CITES was created to ensure that international trade in wild animals and plants does not threaten their survival. Because of massive illegal trade by criminal syndicates, all of Madagascar's rosewood (*Dalbergia* spp., Fabaceae) and ebony (*Diospyros* spp., Ebenaceae) species were listed on CITES Appendix III in 2010 and reclassified to Appendix II in 2013. With this upgrade in the CITES listing of Madagascar's rosewoods and ebonies, a complete moratorium on the sale of these species was imposed. An Action Plan, also adopted by CITES in 2013, which detailed the necessary steps that would have to be taken before Madagascar could resume trading these precious woods. The Plan emphasized understanding the target species' role in trade, assessing their abundance, and establishing infrastructure to control their trade. However, despite the moratorium and the Action Plan, traders in Madagascar have continued to export logs illegally from stockpiles created during the period of civil unrest between 2009 and 2014.

Hery Rajaonarimampianina served as the Minister of Finance and oversaw the General Direction of Customs from 2009 to 2014, during the High Transitional Authority (HAT) period. The HAT was led by Andry Rajoelina, who served as Madagascar's president during this time without having been elected. Rajoelina has since returned to the presidency, serving from 2019 and being re-elected in 2024.

As Madagascar took steps to implement the elements of the Action Plan (Box 1), CITES modified the requirements imposed on Madagascar to acknowledge progress that the country claimed to have made. To date, none of the individual components of the Action Plan have been fully implemented.

On 13 November 2022, at the 75th Standing Committee meeting of CITES, Madagascar announced plans to remove 30,000 rosewood and ebony logs from CITES jurisdiction and make them available to the country's domestic trade. Madagascar stated that the logs would be used exclusively for governmental projects or for the creation of local artisan craft items to be sold in country (Box 2, Figure 1). The handicrafts could weigh no more than 10 kilograms per item and could only be sold in the "domestic" market. The plan did not include any details on tracking the logs removed from the stockpiles, nor was anything specified which governmental projects could receive allocated logs or how Madagascar would ensure that the logs and handicrafts would not enter the international trade. The removal of these logs from CITES jurisdiction with the glaring omission of any details on their management or the supervision of the domestic trade raises serious concerns as to whether this move would potentially lead to international trade in Malagasy rosewood and ebony, which would be in direct contravention of Madagascar's obligations under CITES.

During the 19th Conference of the Parties (CoP19)—14 to 25 November 2022,—Decision 19.71 was adopted, which reduced Madagascar's commitments under the Action Plan to just one obligation: "to bolster its management of rosewood and ebony stockpiles through measures that include traceability and control systems." Madagascar was also urged to seek financial and technical assistance and to provide regular updates on audited inventories and on progress regarding the development and utilization of oversight mechanisms. At CoP19, the Parties did not act on Madagascar's proposal to expand domestic trade in rosewood and ebony using the country's stockpile because the Chair of the Working Committee stated that the Parties should not take any action as the proposal involved "domestic" trade and, therefore, was not under CITES' jurisdiction. CoP19 therefore left consideration of the proposal to remove these logs from CITES jurisdiction to the 77th Standing Committee Meeting. Updates on Madagascar's progress toward meeting its sole remaining obligation were therefore to be submitted for consideration by the Standing Committee. Additionally, Madagascar was instructed to report progress on implementing these measures to the CITES Secretariat 60 days before both the 77th and 78th meetings of the Standing Committee.

During the 77th CITES Standing Committee meeting that occurred in November 2023 in Geneva, the World Wildlife Fund (WWF), representing several non-governmental organizations (NGOs), called on the Parties to create an intersessional working group to ensure that the expansion of Madagascar's "domestic" trade did not instigate illegal international trade or pose a risk to the remaining living Malagasy rosewood and ebony populations. The United States and the European Union advocated for mechanisms to ensure that the "official" stockpiles are not used to launder freshly cut trees, which would further threaten the listed species. The Committee agreed and decided that the Consultative

Box 1. Rosewood Action Plan

The World Bank prepared a report (Mason et al. 2016) assessing the status and future potential of managing Madagascar's precious hardwoods—species of *Dalbergia* (Fabaceae; rosewood) and of *Diospyros* (Ebenaceae; ebony). The report highlighted the significant role these genera play in both local ecosystems and the global market. Prepared in collaboration with the World Resources Institute and other organizations, the report aimed to support the implementation of the CITES Action Plan, which includes improving species identification, enforcing trade regulations, and managing stockpiles.

The findings revealed significant gaps in scientific understanding and enforcement capabilities that needed to be addressed to ensure the sustainable exploitation and conservation of these valuable species. Key measures recommended included:

- A ban on the trade of rosewood and ebony until Madagascar can properly identify and manage the species being harvested.
- Developing materials to help customs officials identify Madagascar's rosewood and ebony species.
- Conducting audits and securing stockpiles of rosewood to prevent illegal exports.
- Strengthening domestic enforcement capacities to manage forests effectively.
- Providing CITES with regular updates on the implementation of these measures.

The report championed the enhancement of the scientific and regulatory frameworks required for the sustainable management of Madagascar's precious hardwoods. This support was regarded as crucial because of the economic potential these resources hold for Madagascar's development. CITES used these findings to implore Madagascar to comply with international standards by imposing stricter export controls and auditing of stockpiles. These measures aimed to curb illegal logging and trade, ensuring that the exploitation of these resources would not threaten the survival of these species or the ecosystems they inhabit.

Box 2. Timeline of Key Events Related to Madagascar's Rosewood and Ebony Trade

• 2000 (October): Moratorium on rosewood and ebony export imposed by Madagascar to halt logging and trade from sensitive zones and protected areas.
• 2006 (September): Explicit ban on the exploitation of rosewood (*Dalbergia* spp., Fabaceae) and ebony (*Diospyros* spp., Ebenaceae) issued by Interministerial Decree No. 16.030/2006.
• 2009 (March): Coup d'état in Madagascar, resulting in a surge of illegal logging of rosewood and ebony.
• 2009–2010: Large-scale illegal sourcing of precious woods from protected areas.
• 2010 (March): Madagascar confirmed a ban on the harvesting of rosewood and ebony through Decree No. 2010-141 of 24 March 2010.
• 2011 (August): Madagascar established penalties for offenses related to rosewood and ebony with Ordinance No. 2011-001 of 8 August 2011 and announced its intention to restrict international trade in five *Dalbergia* species and 104 *Diospyros* species by placing all logs, sawn wood, and veneer sheets of these species on CITES Appendix III.
• 2013 (March): All Malagasy species of *Dalbergia* and *Diospyros* were listed on CITES Appendix II and a complete moratorium on the sale of these species was imposed, alongside the adoption of an Action Plan by CITES outlining steps Madagascar had to take before the moratorium on trade in these species could be lifted.
• 2016 (January): Preliminary findings from an ongoing stockpile audit were presented by Madagascar at the 65th CITES Standing Committee meeting.
• 2019 (August): During CITES COP18, controls on trade in Madagascar's Dalbergia spp. and Diospyros spp. were discussed in depth and reaffirmed.
• 2022 (November): At the 75th Standing Committee meeting, prior to COP19, Madagascar announced its plan to remove 30,000 rosewood and ebony logs from CITES jurisdiction by creating a domestic trade to utilize these logs.
• 2022 (December): During the 19th Conference of the Parties (CoP19), Decision 19.71 was adopted, reducing Madagascar's obligations under the Action Plan to only one requirement: management of its rosewood and ebony stockpiles through practical measures, including traceability and control systems.
• 2023 (November): During the 77th CITES Standing Committee meeting, several NGOs called for the creation of an intersessional working group and the implementation of mechanisms to ensure that the official stockpiles are not used to launder freshly cut trees. The Committee adopted a decision to reconvene the Consultative Group, which was to be created after CoP18 to oversee the use of the stockpiles. This decision expanded the Consultative Group's mandate to include supervision and control of Madagascar's domestic trade in rosewood and ebony.
• 2024 (September): The CITES Secretariat has thus far failed to implement the decision of the 77th CITES Standing Committee to reestablish the Consultative Group and specify its mandate and membership. Currently, no oversight of Madagascar's domestic trade is taking place.

Group, created after CoP18 would be reconvened to oversee the use of the stockpiles and the protection of Madagascar's rosewood and ebony species.

The Consultative Group's purpose is now to ensure that Madagascar's official stockpiles are secured to prevent them from being used to launder logs from "undeclared" and "hidden" stockpiles or from freshly cut trees. Additionally, the Consultative Group must enable Madagascar to better understand the species in trade and to assess whether legal national trade in its rosewood and ebonies is actually possible without spurring illegal international trade. The Consultative Group's initial mandate did not, however, include oversight and control of domestic trade to ensure that it does not have implications for the control of international trade imposed by CITES, which must be added. To date, the Parties are still waiting for the CITES Secretariat to implement the decision taken at CoP18 and to propose, adopt, and publish the Consultative Group's full mandate and announce its membership. The NGOs that proposed the intersessional working group have called for NGO representation in the Consultative Group.

MAIN CONCERNS

Madagascar's "domestic" trade proposal has shed light on a significant flaw in the structure of CITES, one that could easily serve as a model for avoiding CITES restrictions on trade and undermine CITES' protection of rare and endangered species from the impacts of international trade.

Some of Madagascar's endemic rosewood species are prized for the deep red color of their heartwood. Criminal syndicates, including Chinese rosewood furniture manufacturers, will most certainly jump at the opportunity to exploit Madagascar's domestic trade unless CITES acts to ensure that:
• all necessary steps have been implemented to control domestic trade, including identifying the species in trade, assessing the occurrence and abundance of the exploited species, and understanding whether any sustainable trade of selected species is feasible after the preparation of a properly prepared and formulated non-detriment finding (NDF);
• the official stockpiles are secured in a single controlled location and overseen by an independent, third party approved by the CITES Secretariat;
• all logs removed from these stockpiles are tracked to ensure that they are used exclusively for approved purposes;
• all logs in domestic trade are prevented from being diverted to the international market.

The delay in operationalizing the Consultative Group approved by the Standing Committee at its 77th meeting in November 2023, leaves the stockpiles wide open to illegal trade. The delay also increases the temptation to launder logs from other stockpiles and it could lead to felling additional rosewood and ebony trees. The main concern is therefore that Madagascar's proposed domestic trade, if conducted without appropriate safeguards, could facilitate the illegal international market (cf. Wilmé et al. 2020).

DISCUSSION

To date, despite significant advances in the understanding and description of Madagascar's rosewoods (*Dalbergia* spp.) and ebonies (*Diospyros* spp.), there is still no clear information on which species are being traded, nor is there an accurate assessment of the population status of these species. Consequently, Madagascar cannot prepare a non-detriment finding (NDF) to assess the potential impacts of international export of any of these precious wood species. Moreover, since these key information gaps remain, Madagascar has been unable to produce customs materials and comprehensive forensic tools that would be needed to determine whether exports of rosewood and ebony involve NDF-

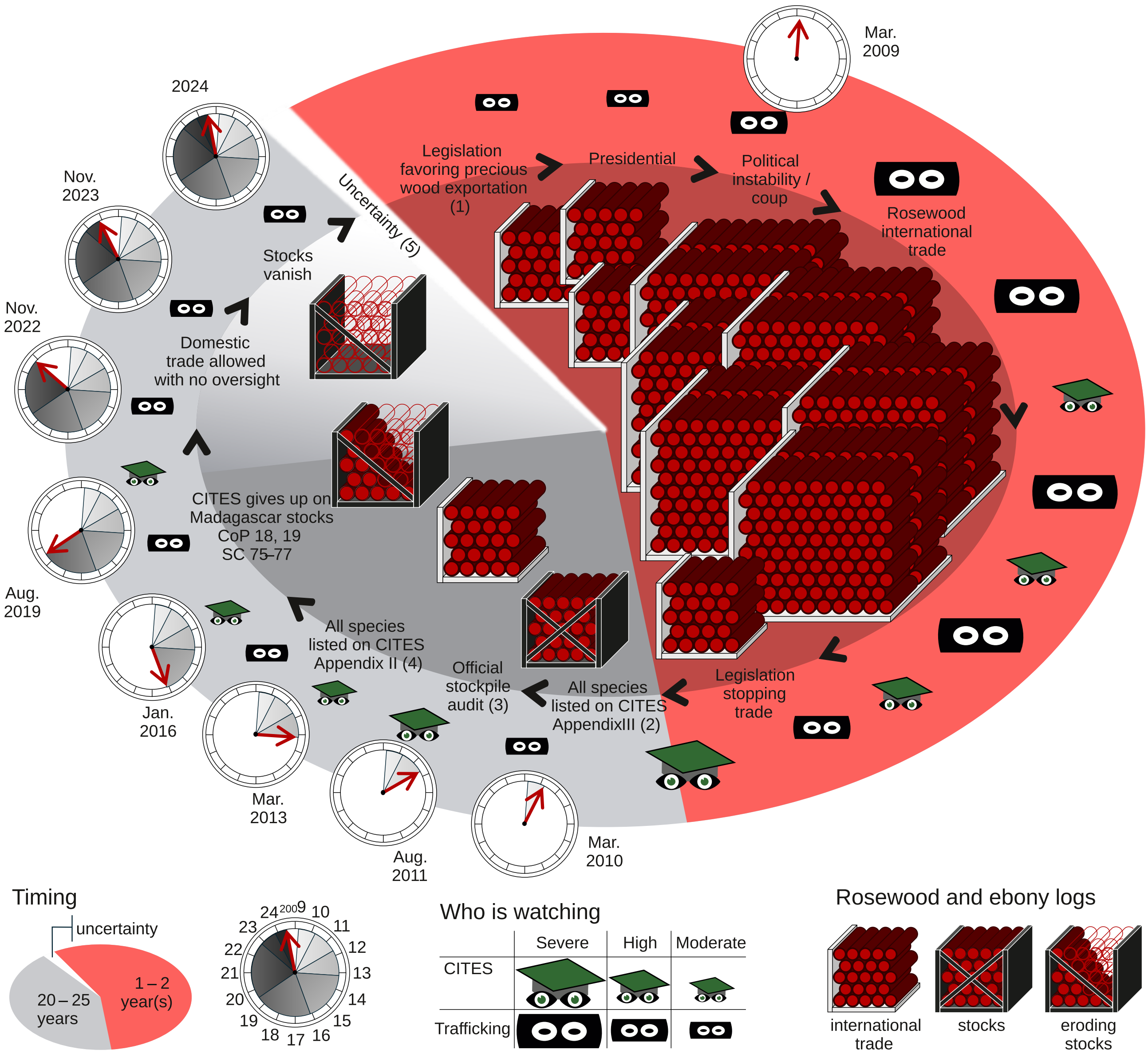

Figure 1. The rosewood trafficking cycle with different time scales and speeds, alongside associated reactions from CITES—supported by research, activism, journalism, and other civil society organizations—and actors involved in precious wood trafficking. (1. Precious wood or rosewood relate to species in the rosewood (*Dalbergia*, Fabaceae) and ebony (*Diospyros*, Ebenaceae) genera; 2. All species of rosewood and ebony from Madagascar; 3. Stocks correspond to the logs seized after the prohibition of international trade and the ban on logging at the national level, whether these logs were seized in Madagascar or elsewhere in the world, including in Singapore, Taiwan, and Kenya; 4. All species of rosewood and ebony from the entire world; 5. Uncertainty and risks that may have started as early as when CITES began to give up on Madagascar rosewood—see August 2019)

approved species or those for which international trade is forbidden. Additionally, Madagascar lacks adequate forest governance and the means to secure and control the hundreds of thousands of rosewood and ebony logs in the "official," "undeclared," and "hidden" stockpiles currently scattered around the country (Wilmé et al. 2020).

As was demonstrated after the one-off sales of ivory that took place in 1999 and 2008, the legalization of trade in a highly sought-after rare or endangered species or its parts often leads to opportunists exploiting relaxed regulations to engage in illegal trade (Hsiang and Sekar 2019). The current conditions regarding Madagascar's rosewood and ebony are similar and therefore do not support making stockpiled logs available for expansion of domestic trade without simultaneously facilitating parallel illegal international trade or an expanded domestic trade.

RISK I: LAUNDERING. The approximately 30,000 rosewood logs in Madagascar's "official" stockpiles have not been secured under the auspices of an independent third party. This engenders a great risk of these stockpiles being used as laundering mechanisms for logs from the country's "undeclared" and "hidden" stockpiles as well as from freshly cut trees. Such laundering could easily be occurring now, while the CITES Secretariat takes its time to reconvene the Consultative Group.

Should Madagascar proceed with domestic commercialization of the "official" stockpiles, it could thus lead to a 'laundering mechanism' and renewed illegal international trafficking. Development and implementation of explicit CITES guidelines is imperative to prevent illegal trade. Madagascar's rosewood and ebony are 'political timber'—past elections have coincided with spikes in sourcing and trafficking from previous stockpiles (Randriamalala and Liu 2010, Waeber et al. 2018, 2019). It is very likely that the criminal syndicates concerned are closely connected to the current government of Madagascar. It is therefore essential that if the logs are to be used for the proposed domestic trade, they be secured by an independent third party approved by the CITES Secretariat prior to the commencement of any commercial activity.

Despite Madagascar's commitment made during CoP 19 to "strengthening the management" of timber stockpiles, there has been minimal actual management of the stockpiles. "Official" stockpiles remain unsecured and no effort has been made to address the management of "undeclared" and "hidden" stockpiles of rosewood and ebony. Furthermore, there is a complete lack of robust traceability and control systems (Waeber et al. 2023). Indeed, historically Madagascar has failed to develop adequate systems for logs used in governmental projects and allocated to artisans. The failure to secure, audit, or even identify "undisclosed" and "hidden" stockpiles, combined with lax measures for managing the official stockpiles, create a potential avenue for laundering logs from these sources. This in turn enhances the risk of illegal international trade.

Domestic usage of timber from the "official" stockpiles was recently implemented by the Madagascar government without discussion at CITES. Logs from official stockpiles were used to repair the Queen's Palace (also known as Anatirova) more than 25 years after the fire that destroyed the original building in 1995. Investigations by the Environmental Investigation Agency (EIA) and Transparency International (TI) could not verify whether all the logs removed from the stockpiles were actually used for repairs to the Palace. This leaves open the possibility that more logs were removed from the stockpiles than needed for the repairs, and that the excess logs were illegally exported (Vyawahare 2022). EIA and TI reported multiple irregularities in the procedures used to approve the project and, in the authorizations, granted for its realization.

Due to a lack of expertise and resources, Madagascar faces disconcerting challenges to define and implement procedures and to guarantee the effective management of regulated trade in precious wooden handicrafts. Clear criteria are required to set withdrawal limits from stockpiles and to apply controls on exports to prevent further illegal international trade. There is currently no definition of what constitutes a 'handicraft' or regulations in place to ensure that entire logs released for the production of handicrafts are indeed transformed into such items. The potential for devious exploitation of handicrafts as sources of material for precious wood industries by operated international players and criminal syndicates reinforces the pressing need for comprehensive safeguards to be put in place.

Despite the bleak scenario outlined above, progress is being made in monitoring and tracking the trade of Madagascar's rosewood and ebony. Species limits have been clarified and their threat status has been assessed (Tropicos 2024a,b). Identification tools have been developed for standing trees although they are not yet available for felled trees or cut wood. Currently, methods are being tested for selected species using wood anatomical features (Musinsky et al. 2018, Sandratriniaina et al. 2021) as well as NIRS and DART TOFMS spectral signatures, and DNA barcoding tools are also being piloted. These methods could be complemented by convolution neural networks and chemotyping (Espinoza et al. 2015, He et al. 2018, Rocha et al. 2021). Techniques for near real-time forest monitoring notably of illegal activities are also in development (Musinsky et al. 2018).

However, innovative techniques for monitoring and tracking are only useful if accompanied by effective enforcement. The CITES Consultative Group must establish controls on Madagascar's domestic trade that effectively prevent the illegal export of these precious woods. Environmental crime will decrease only when the trinity of robust monitoring, enforcement, and prosecution are fully established and operational.

RISK II: POTENTIAL EXPLOITATION OF FRESHLY CUT TREES. Freshly cut rosewood and ebony are likely to be laundered through official stockpiles. Mixing illegally sourced items into legal channels, a form of greenwashing, is a significant problem in the trafficking of wildlife and forest-derived products (Keskin et al. 2023). Legalizing domestic use without first securing the stockpiles, preventing the addition of newly harvested logs, and preventing export to the international market could encourage more unsustainable exploitation of the remaining Malagasy rosewood and ebony trees. The value of freshly cut wood exceeds that of decade-old logs in the stockpiles. Felling live rosewood or ebony trees to meet increased demand would negatively impact the chances of survival of these species and adversely impact Madagascar's forests and biodiversity (Sawyer et al. 2017, Vasey et al. 2018).

RISK III: MISUSE OF LOGS IN DOMESTIC TRADE. Since the 1980s, Madagascar forestry sector has faced persistent challenges, including weak governance, insufficient law enforcement, poor practices, and unclear regulations, all exacerbated by rampant corruption (Duffy 2005, McConnell and Sweeney 2005, Raik 2009, Randriamalala and Liu 2010, Scales 2012). This situation has led to the ongoing depletion of Madagascar's endemic rosewoods and ebonies (along with other timber species). Mediocre governance and ambiguous regulations have created an environment conducive to timber trafficking, particularly during periods of political instability such as 1992, 2006, and 2009–2010 (Schuurman and Lowry 2009, Innes 2010, Randriamalala and Liu 2010, Roberts et al. 2022). Upsurges in rosewood exports are often facilitated by strategically timed government decrees issued before elections or amid political turmoil. These official acts, coupled with "exceptional" government orders, empower a select few influential operators to export significant quantities of wood with official approval, highlighting the systemic failures in Madagascar's forestry management (Randriamalala and Liu 2010, Wilmé et al. 2018).

No effort has been made by Madagascar to define the criteria and procedures to be used to decide which artisans will be permitted to participate in the expanded domestic trade. There is a considerable risk that members of criminal syndicates will attempt to register as handicraft makers, and procedures will therefore be needed to prevent this from happening (Wilmé et al. 2020). Additionally, the government currently lacks guidelines to determine what criteria will be used to determine projects qualify for the use of logs from the official stockpiles, how many logs will be required for a project, and what measures will be taken to track the logs released to be sure that they are actually used in the approved project and not diverted for illegal sale. Adequate governance must be established to ensure that logs removed from the stockpiles for governmental projects are used appropriately. Mitigating these issues will require identifying qualified artisans and appropriate governmental projects along with tracking logs to be sure that they are used as intended.

RECOMMENDATIONS

In the current context of Madagascar, the risks associated with a domestic trade in rosewood and ebony are high and threaten to undermine efforts made by CITES to ensure that international trade, both legal and illegal, does not threaten the survival of native species. Given the high demand for Malagasy rosewood and ebony, which highly threatened (Tropicos 2024a,b), comprehensive solutions to mitigate the risks identified above must be implemented before the CITES Standing Committee can be sure that the proposed domestic trade will not undermine current efforts and the embargo that implemented by CITES. The Consultative Group must be reactivated and needs to move aggressively. A realistic solution would be to curtail both international and domestic trade of Malagasy *Dalbergia* spp. and *Diospyros* spp. until effective controls are fully implemented.

To ensure that Madagascar's proposed use of stockpiled rosewood and ebony logs does not undermine ongoing conservation efforts supported by CITES, the following steps must be taken. These measures are essential to safeguard the remaining populations of these species from the threats posed by both international and domestic trade:

• Operationalize the Consultative Group with a broad mandate and NGO representation to address the issues identified above.

• Create a documentation and marking system to validate the legal acquisition of logs for domestic construction and artisanal purposes, and establish clear criteria for qualifying projects, artisans, and handicraft items, along with mechanisms to guarantee full utilization of allocated logs and traceability of handicrafts to their origins. These measures are vital for ensuring the legality, transparency, and sustainability of trade.

• Establish an independent, third-party monitor to oversee all aspects of Madagascar's domestic trade in an effective and transparent manner.

• Secure the official stockpiles and implement a reliable inventory and marking system before any utilization or trade. Consolidate all logs into a single, secured location and develop a robust control and a tracking system for released logs.

CONCLUSION

An expansion of domestic trade in Madagascar's rosewood and ebony using stockpiled logs without stringent oversight and effective control and enforcement measures poses severe risks to global conservation efforts. The inability to identify species along the entire supply chain and to assess their populations, combined with inadequate traceability and governance, create a high potential for illegal activities such as laundering freshly cut logs through official stockpiles. The CITES Secretariat has yet to implement the Standing Committee decision to reactivate the Consultative Group, which is critical before Madagascar is allowed to utilize the 30,000 logs in the "official" stockpiles for domestic trade. Otherwise, the efforts of CITES to protect Madagascar's CITES Appendix II listed rosewood (*Dalbergia* spp., Fabaceae) and ebony (*Diospyros* spp., Ebenaceae) species are likely to be profoundly compromised.

Madagascar's proposed expansion of its domestic trade in species of highly prized rosewood and ebony listed on Appendix II, if implemented, will function as a test case for other countries that are considering similar moves involving valuable rare and endangered species. CITES' actions in this matter will, for example, influence the policies of Southern African countries on ivory and rhino horn trades, and China's potential domestic trade in pangolins and tigers and their parts. The stakes are enormous; if countries can evade CITES controls by selling rare and endangered species domestically, the ability of CITES to protect these species from excessive international trade and potential extinction will be severely undermined.

It is imperative that all of Madagascar's stockpiles established during the recent period of civil unrest remain under strict CITES embargo, and that supervision, with comprehensive, effective enforcement mechanisms be implemented to prevent illegal international trade. Ensuring robust safeguards and stringent controls is essential to the success of CITES in protecting and averting the extinction of traded species globally. The consequences of inadequate regulation and enforcement could set a dangerous precedent for international wildlife conservation.

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Lémuriens de l'Aire Protégée Complexe Tsimembo Manambolomaty, région Melaky, Madagascar : Diversité et estimation de la densité

Heritiana J. Randriamanantena[1], Hanta Razafindraibe[1], Aristide Andrianarimisa, Marius P. H. Rakotondratsima[2], Donatien Randrianjafiniasa[2], Gilbert Razafimanjato[2], Lily-Arison Rene de Roland[2]

Correspondence:
Heritiana J. Randriamanantena
Mention Zoologie et Biodiversité Animale
Université d'Antananarivo
BP 906
Antananarivo 101
Email: josolegothik@gmail.com

ABSTRACT

Lemurs, one of the most diverse species of primates; are facing a critical decline in population size due to anthropogenic pressures. This study investigates the dynamics of lemur diversity and abundance in the Tsimembo forest between 1998 and 2017. Data collection involved direct observations along seven transects, supplemented with additional observations. Lemur assessments were conducted at the start of the wet season in 2016 and 2017, while bibliographic data from 1998 and 2015 were utilized to assess changes in estimated species density. A total of eight lemurs were observed, including *Propithecus deckenii*, *Eulemur rufus*, *Hapalemur griseus ranomafanensis*, *Microcebus* sp., *Mirza coquereli*, *Cheirogaleus medius*, *Phaner pallescens* and *Lepilemur* sp. notably, six of those are currently at risk of extinction. The mouse lemur and sportive lemur exhibit multi color variations, posing challenges to species determination. The Tsimembo forest lemur population is characterized by the dominance of nocturnal species and Decken's sifaka. The density of *P. deckenii* increased from 98 individuals/km^2 in 1998 to 170 individuals/km^2 in 2017. In contrast, *E. rufus* density significantly decreased from 170 individuals/km^2 in 1998 to just 2 individuals/km^2 in 2017. *Lepilemur* sp. Population declined from 573 individuals/km^2 to 100 individuals/km^2 in 2016, with a subsequent increase to 120 individuals/km^2 in 2017. Most recorded species displayed stabilization and even growth between 2016 and 2017. Species-specific identification of mouse lemurs and sportive lemurs requires cytogenetic studies. Existing literature suggest the potential presence of two species of mouse lemur *M. murinus* and *M. myoxinus*, in the Tsimembo forest, while the sportive lemur may belong to either *L. ruficaudatus* or *L. randrianosoloi*. These findings provide valuable insights into lemur population dynamics and highlight the need for conservation efforts in this diverse and threatened primate community.

RÉSUMÉ

Les lémuriens, parmi les primates les plus diversifiés, voient malheureusement leur effectif décliner au fil du temps et de l'espace, principalement en raison des pressions anthropiques. Cette étude vise principalement à élucider la diversité et l'abondance des communautés de lémuriens dans la forêt de Tsimembo sur la période de 1998 à 2017. La méthode a impliqué des observations directes le long de sept transects, complétées par des observations supplémentaires. Le comptage des lémuriens a été réalisé au début de la saison humide en 2016 et en 2017. Des données bibliographiques portant sur les années 1998 et 2015 ont également été utilisées afin d'éclaircir l'évolution de la densité estimée de chaque espèce. Huit lémuriens dont *Propithecus deckenii*, *Eulemur rufus*, *Hapalemur griseus ranomafanensis*, *Microcebus* sp., *Mirza coquereli*, *Cheirogaleus medius*, *Phaner pallescens* et *Lepilemur* sp. ont été inventoriés. La densité est marquée par la dominance des espèces à mœurs nocturnes et de *P. deckenii*. La densité de certaines espèces a connu une fluctuation depuis 1998, avant de se stabiliser en 2017. Une légère augmentation de la majorité des espèces recensées est notée entre 2016 et 2017. Toutefois, l'identification spécifique des microcèbes et des lépilémurs nécessite des études cytogénétiques, sachant qu'il pourrait s'agir de *Microcebus* murinus et *M. myoxinus*, ainsi que de *Lepilemur ruficaudatus* et *L. randrianosoloi* d'après la littérature.

INTRODUCTION

Les lémuriens sont des primates endémiques de Madagascar dont la plupart dépendent entièrement de la forêt. Actuellement, ils comptent 113 espèces et figurent parmi les primates les plus diversifiés au monde (Schüßler et al. 2020). La taille de leur population continue à diminuer dans le temps et dans l'espace (UICN 2020). Les lémuriens strictement forestiers sont les plus

1 Mention Zoologie et Biodiversité Animale, Université d'Antananarivo, BP 906, Antananarivo 101
2 The Peregrine Fund, BP VA 26 AH Tsiadana, Antananarivo 101
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vulnérables à cause de la réduction de la couverture de leur habitat. Sur la période 1950-2000, Madagascar a perdu environ 40 % de sa couverture forestière (Harper et al. 2007, Vieilledent et al. 2018). Le taux de déforestation était de 1,4 % à 4,7 % en 1990 sur la totalité du pays (Achard et al. 2002). Une intensification de la diminution de l'abondance et de la densité des lémuriens a été ainsi été proposée au fil du temps dans plusieurs parties de l'île (Dammhahn et al. 2009, Gardner 2009, Rakotondratsimba et al. 2013, Gudiel et al. 2017, Anania et al. 2021).

Les forêts sèches malgaches hébergent environ 25 espèces de lémuriens (Ralison, 2008). Elles subissent de fortes pressions liées aux activités humaines (Soarimalala et Raherilalao 2008). Les forêts de Tsimembo forment un des plus grands blocs dans l'ouest de l'île et couvrent d'environ 32800 ha. Elles constituent un refuge pour de nombreuses espèces de lémuriens, dont certaines sont en danger critique d'extinction (Bousquet et Rabetaliana 1992, Ausilio et Raveloanrinoro 1998, Razanantsoa 2000, Rabearivony et al. 2010). En revanche, les menaces y sont réelles avec la chasse aux lémuriens, les feux de brousse, la coupe sélective de bois ainsi que la collecte destructive de miel et d'ignames qui ont été signalées depuis quelques années. Suite aux efforts de conservation menés par The Peregrine Fund (TPF), la zone incluant la forêt de Tsimembo a été classée Site RAMSAR en 1999 et a obtenu un statut d'Aire Protégée catégorie V en 2008 (Rabearivony et al. 2010).

Les recherches précédentes effectuées dans l'Aire Protégée Complexe Tsimembo Manambolomaty avaient mis en évidence la présence de 10 espèces de lémuriens, dont une diurne (*Propithecus deckenii*), deux cathémérales (*Eulemur rufus* et *Hapalemur griseus ranomafanensis*) et huit nocturnes (*Cheirogaleus medius*, *Lepilemur ruficaudatus* et *L. randrianasoloi*, *Microcebus murinus* et *M. myoxinus*, *Mirza coquereli*, *Phaner pallescens* et *Daubentonia madagascariensis*) (Bousquet et Rabetaliana 1992, Ausilio et Raveloanrinoro 1998). La présence de neuf nids inhabités de *Daubentonia madagascariensis* avait été répertoriée en 1994 (Sterling 1998). Les recensements antérieurs avaient aussi constaté une forte concentration de populations de lémuriens dans cette forêt (Bousquet et Rabetaliana 1992, Ausilio et Raveloanrinoro 1998, Randriamanantena et al. 2019). Les informations concernant portant sur les communautés de lémuriens dans l'Aire Protégée restaient néanmoins rudimentaires d'autant que les données démographiques évoluent dans le temps et dans l'espace selon le degré de pression auquel les populations sont soumises. La présente étude s'attache ainsi à élucider la diversité et l'abondance des communautés des lémuriens dans cette zone entre 1998 et 2017.

MÉTHODOLOGIE

PÉRIODE ET SITE D'ÉTUDE. L'étude sur le terrain a été réalisée durant le début de la saison humide du mois de novembre à décembre 2016 et de novembre à décembre 2017 dans la forêt de Tsimembo. Avec une superficie de 62745 ha, l'Aire Protégée Complexe Tsimembo Manambolomaty est localisée dans la partie ouest de Madagascar, région Melaky, district d'Antsalova, à cheval sur les communes de Masoarivo, Trangahy et Antsalova (Figure 1). La forêt de Tsimembo occupe une grande partie de l'Aire Protégée et couvre environ 32800 ha.

Sept sites d'étude ont été inventoriés dont trois sites à l'intérieur du bloc forestier et quatre sites sur la périphérie (Tableau 1). Les sites situés à l'intérieur du bloc forestier étaient plus ou moins intactes ; il s'agit d'Analalava, Antranoviky et Bemolaka. Quelques coupes sélectives d'arbres pour la fabrication de pirogues traditionnelles y ont été relevées. Les sites situés à la périphérie du bloc forestier ou près des villages étaient plus dégradés ; il s'agit d'Ambaratamalinika, Ambondromifindra, Ankoabitika et Soavala. Les perturbations relevées étaient la coupe sélective d'arbres, la culture sur brûlis ou *Hatsaka* et les feux de brousse.

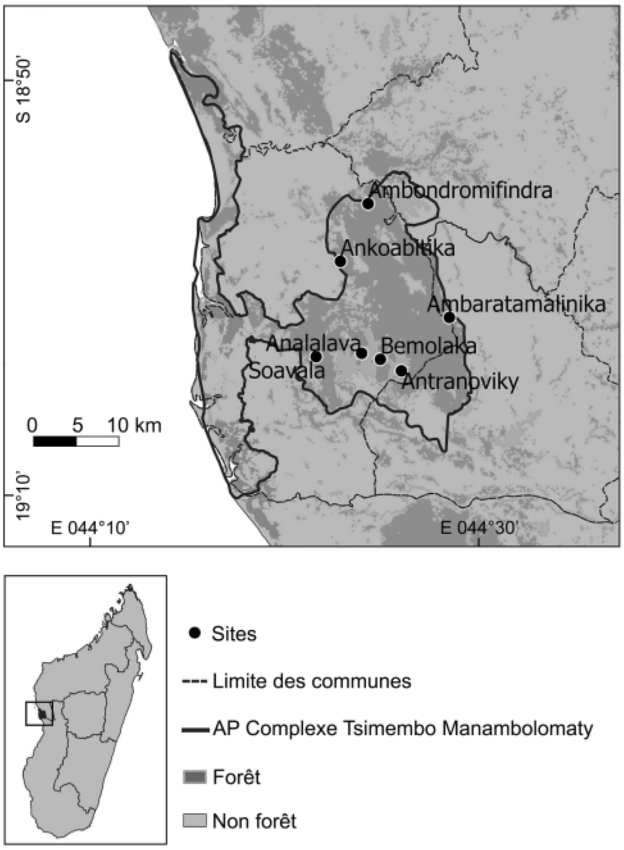

Figure 1. Localisation de l'Aire Protégée Complexe Tsimembo Manambolomaty.

INVENTAIRE ET RECENSEMENT. L'inventaire et le comptage des lémuriens ont été réalisés par observation directe le long d'itinéraires échantillons ou transect (Brockelman et Ali 1987). Il s'agissait de marcher à une vitesse constante comprise entre 0,5 à 1 km/h et de compter tous les individus rencontrés des deux côtés du transect. La visite se déroulait pendant les heures d'activité des lémuriens, soit entre 0600h et 0900h du matin pour les espèces diurnes, et entre 1800h et 2100h pour les espèces nocturnes. Ces dernières étaient repérées par la réflexion du tapetum lucidium au contact de la lumière d'une lampe frontale de faible intensité. Les individus ont alors étéidentifiés en utilisant une torche de forte intensité. La distance perpendiculaire au transect de chaque individu rencontré a été notée pour pouvoir calculer la densité (Whitesides et al. 1988). Au total, sept transects permanents ont été utilisés (Tableau 1). Chaque transect était marqué par une bande en plastique de couleur vive tous les 10 m.

Tableau 1. Localisation des sites et longueur (m) de chaque transect d'étude.

Sites	Longueur du transect (m)	Position géographique
Analalava	1000	E044° 25' 15'', S19° 00' 55''
Antranoviky	1000	E044° 27' 54'', S19° 02' 04''
Bemolaka	1000	E044° 26' 30'', S19° 01' 19''
Ambaratamalinika	1000	E044° 31' 09'', S18° 58' 42''
Ambondromifindra	1000	E044° 25' 48'', S18° 51' 24''
Ankoabitika	1000	E044° 23' 54'', S18° 55' 03''
Soavala	2000	E044° 22' 12'', S19° 01' 06''

OBSERVATION COMPLÉMENTAIRE. L'observation complémentaire consiste à explorer les zones en dehors des transects pour détecter les espèces cryptiques. Certaines espèces extrêmement, rares peuvent être révélées par la moindre trace d'activité ou un cri. Le parcours est souvent déterminé en fonction de l'écologie de l'espèce recherchée.

IDENTIFICATION DE CHAQUE INDIVIDU. L'identification de chaque espèce de lémuriens est basée sur des critères définis par les recherches antérieures (Tattersall 1987, Rasoloarison et al. 2000, Andriaholinirina et al. 2006, Ankel-Simons 2007). Ces critères s'agissent de la taille, la couleur du pelage, le cri, le nom vernaculaire ainsi que le comportement de chaque animal.

ANALYSE DES DONNÉES. Analyse de la distance de détection. Le test de Wilcoxon a été utilisé pour analyser la distance moyenne de détection d'individus entre les lémuriens. Il a également été employé pour vérifier l'homogénéité de cette distance de détection pendant la saison de comptage de 2016 et celle de 2017 pour chaque espèce.

CALCUL DE LA DENSITÉ APPROXIMATIVE. La méthode de Whitesides et al. (1988) a été utilisée pour estimer la densité de chaque espèce. Elle nécessite l'estimation de la distance perpendiculaire par rapport au transect de chaque individu observé selon la formule :

$$d = \frac{n}{(2wL)}$$

avec d pour la densité estimée d'une espèce, n pour le nombre d'individus recensés d'une espèce, w pour la distance moyenne perpendiculaire par rapport au transect des individus rencontrés et L pour la longueur totale du transect parcouru.

Cette méthode a été fréquemment utilisée pour les lémuriens et autres primates non-humains (Ganzhorn 1994, Ralison 2008, Rakotondratsimba et al. 2013). Dans notre étude, elle a été adoptée pour comparer nos résultats avec ceux obtenus précédemment dans la forêt de Tsimembo, c'est-à-dire les résultats de recensements réalisés en 1998 et 2015 (Ausilio et Raveloanrnoro 1998, Randriamanantena et al. 2019).

RÉSULTATS

DIVERSITÉ SPÉCIFIQUE. Au moins huit espèces de lémuriens ont été recensées dans l'Aire Protégée Complexe Tsimembo Manambolomaty dont trois espèces diurnes et cinq espèces nocturnes (Tableau 2).La forêt de Tsimembo héberge au moins quatre espèces menacées d'extinction au minimum. Le statut de *Propithecus deckenii* est passé de en danger (EN) à en danger critique d'extinction (CR) depuis décembre 2019 (UICN 2020). Les espèces *Mirza coquereli* et *Phaner pallescens* sont classées en danger (EN). L'identification des espèces dans les genres *Microcebus* et *Lepilemeur* n'est pas résolue mais pourrait porter ce chiffre à six espèces menacées.

Il y a deux variations morphologiques observées chez les espèces du genre *Microcebus*. La première possède un pelage de couleur marron foncé avec des oreilles plus arrondies. La deuxième est de couleur orangée avec des oreilles plus pointues. Sur le terrain, la distinction s'avère très difficile car ces deux caractères sont de nature cryptique.

Tableau 2. Les espèces inventoriées dans l'Aire Protégée Complexe Tsimembo Manambolomaty. (CR = En danger Critique, EN = en danger, VU = Vulnérable)

Mœurs	Familles	Espèces	Statut UICN
Diurne	Indriidae	*Propithecus deckenii*	CR
	Lemuridae	*Eulemur rufus*	VU
		Hapalemur griseus ranomafaniensis	VU
Nocturne	Cheirogalidae	*Microcebus* sp.	-
		Mirza coquereli	EN
		Cheirogaleus medius	VU
		Phaner pallescens	EN
	Lepilemuridae	*Lepilemur* sp.	-

D'après les observations, il y a également deux variations morphologiques de *Lepilemur* qui pourraient être rencontrées dans le site d'études. La première possède un pelage marron sur la partie dorsale, et marron plus foncé sur la partie de l'épaule et de l'avant-bras. La partie ventrale est gris clair. La queue est de couleur marron encore plus foncé que le pelage dorsal. Le museau est noir foncé et plus pointu. L'intérieur des oreilles est de couleur plus sombre. La seconde possède un pelage gris-marron plus clair sur la partie dorsale et gris clair sur la partie ventrale. L'épaule et l'avant-bras sont marqués par un pelage orangé très distinct. La queue est orangé clair, parfois avec une pointe blanche. Le museau est gris et plus flasque. L'intérieur des oreilles est de couleur plus claire.

DENSITÉ APPROXIMATIVE DES LÉMURIENS. Un total de 24 km de transect a été parcouru en 2016 et de 21 km en 2017 pour les observations diurnes. Seul le site d'Ambondromifindra n'a pas été re-visité en 2017. Pour l'effort d'observation nocturne, 17 km ont été parcourus pour chaque saison dans les cinq sites de comptage. La distance de détection moyenne des espèces diurnes variait de 5,7 m à 19,0 m (n = 133) (Figure 2). Celle des espèces nocturnes était comprise entre 4,0 m et 13,0 m (n = 377). Les espèces qui sont généralement de grande taille étaient plus faciles à détecter par rapport aux espèces nocturnes plus petites selon le test de Wilcoxon (W = 56, p = 0,002). La distance de détection moyenne restait homogène pour chaque espèce pendant les deux saisons de comptage (W = 24, p = 0,441).

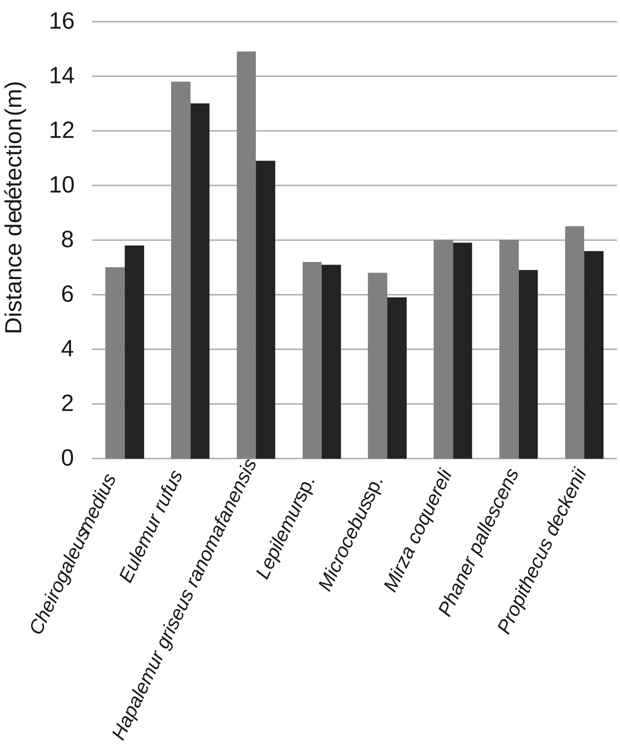

Figure 2. Distance perpendiculaire moyenne entre le transect et l'emplacement des individus observés par espèce durant les comptages en 2016 et 2017

Le nombre d'individus observé en 2017 était légèrement plus élevé qu'en 2016 et cela pour la majorité des espèces. Environ une cinquantaine d'individus avaient été rencontrés durant chaque saison de comptage pour *Propithecus deckenii*, *Microcebus* sp. et de *Phaner pallescens*. La densité approximative était marquée par la dominance des espèces nocturnes, surtout *Microcebus* sp. et *Phaner pallescens* (Tableau 3).

Famille des Indriidae. *Propithecus deckenii* ou Propithèque de Decken ou Sifaka. *Propithecus deckenii* est une espèce diurne, commune à tous les sites d'inventaire étudiés. Sa densité était élevée à Ambaratamalinika et Antranoviky, et proche de 300 ind./km² (Tableau 3). L'espèce semblait moins abondante dans les sites perturbés tels qu'Ankoabitika et Soavala.

Famille des Lemuridae. *Eulemur rufus* ou Lémurien à front roux ou *Gidro*. Cette espèce était farouche et généralement observée en dehors des transects de comptage. La présence d'*Eulemur rufus* n'a été confirmée que par les observations complémentaires dans quatre des six sites d'étude. En 2017, deux individus avaient été observés à Soavala pendant le comptage nocturne et six autres avaient été répertoriés pendant les observations complémentaires à Ambaratamalinika, Analalava et à Bemolaka. Ces animaux n'ont pas été inclus dans le calcul de la densité approximative. L'espèce semble peu abondante car la densité maximale n'atteignait que 13 ind./km² en 2017 (Tableau 3).

Hapalemur griseus ranomafanensis ou Hapalémur gris ou *Bekolà*. Cette espèce a un régime alimentaire spécialisé et composé de bambous ou *Viky*, de sorte que sa distribution est liée à la présence de cette plante qui est généralement confinée près des points d'eau. *Hapalemur griseus ranomafanensis* a été occasionnellement rencontrée en dehors des transects, une fois à Antranoviky et trois fois à Bemolaka. Aucun individu n'a été recensé hors des transects en 2016. Cette espèce vit en groupe familiaux, bien qu'il y ait des individus solitaires. Sa densité reste très faible et dépasse rarement les 10 ind./km² (Tableau 3).

Famille des Cheirogaleidae. *Microcebus* sp. ou Microcèbe ou *Tilitilivahy*. Les microcèbes sont des lémuriens de petite taille largement distribués dans la forêt de Tsimembo. Ils sont abondants, davantage dans les sites à l'intérieur de la forêt que ceux de la périphérie. Leur densité dépassait souvent 500 ind./km² (Tableau 3). Des microcèbes ont été observés dans des broussailles près du village d'Ambereny à proximité de la forêt d'Ankoabitika.

Tableau 3. Densité estimée par espèce dans chaque site en 2016 et 2017. (* ind/ km², na† = exclu de l'observation nocturne, na§ = Exclu de l'observation diurne, Ambar = Ambaratamalinika, Ambon = Ambondromifindra, Anala = Analalava, Ankoa = Ankoabitika, Antra = Antranoviky, Bemol = Bemolaka, Soava = Soavala)

		Sites						
Espèces	Années	Ambar	Ambon	Anala	Ankoa	Antra	Bemol	Soava
Propithecus deckenii	2016	239	104	176	19	296	144	82
	2017	297	na§	126	91	270	151	87
Eulemur rufus	2016	42	0	111	9	0	68	0
	2017	0	na§	0	0	0	0	13
Hapalemur griseus	2016	0	0	0	0	11	0	0
ranomafanensis	2017	0	na§	45	0	0	0	0
	2016	na†	na†	120	565	185	673	113
Microcebus sp.	2017	na†	na†	265	500	366	542	148
	2016	na†	na†	71	45	75	67	10
Mirza coquereli	2017	na†	na†	68	56	89	151	20
	2016	na†	na†	111	103	68	148	101
Cheirogaleus medius	2017	na†	na†	167	195	123	107	129
	2016	na†	na†	730	13	387	231	30
Phaner pallescens	2017	na†	na†	575	98	361	407	82
	2016	na†	na†	76	154	162	67	79
Lepilemur sp.	2017	na†	na†	144	179	134	97	72

Cheirogaleus medius ou Cheirogale moyen ou *Kelibehoy*. L'espèce était commune lors de toutes les visites nocturnes dans la forêt de Tsimembo. Elle était facilement reconnaissable grâce à son comportement lors de ses déplacements en rampant sur les branches et restait habituellement stationnaire. Elle sort généralement de sa période d'hibernation vers mi-octobre. Sa densité dépassait les 100 ind./km² dans chaque site (Tableau 3).

Phaner pallescens ou Lémurien à fourche ou *Tanta*. *Phaner pallescens* est caractérisée par deux bandes noires partant du dessus des yeux, qui se rejointgent à l'arrière du cou pour former un « Y » dans le dos. Elle est réputée pour être vocale. Elle était abondante dans les parties plus intactes à l'intérieur de la forêt comme à Analalava, Antranoviky et Bemolaka. Sa densité variait de 13 à 730 ind./km² en 2016 et 82 à 575 ind./km² en 2017 (Tableau 3).

Mirza coquereli ou Microcèbe géant de Coquerel ou *Kifonjitsy*. Cette espèce montre un pelage grisâtre teinté de roux clair sur le dos et plus clair sur la partie ventrale. La queue de tous les individus observés était roux foncé virant au noir sur le bout des poils. Les poils étaient de plus en plus longs et fins vers le bout de la queue. *Mirza coquereli* était le lémurien nocturne le moins abondant de l'Aire Complexe Tsimembo Manamambolomaty. Sa densité dépassait rarement 100 ind./km² avec environ 10 ind./km² en 2016 et 20 ind./km² en 2017 à Soavala près du village de Masoarivo (Tableau 3) mais des densités plus importantes à Antranoviky et à Bemolaka.

Famille des Lepilemuridae. *Lepilemur* sp. ou lépilémur ou *Boenga*. Deux variations de couleur des lépilemurs des sites étudiés ont été confirmées par des photos prises sur quelques individus. Il est donc difficile de quantifier les individus en fonction de ces variations, d'autant que les lépilémurs restaient principalement dans des trous d'arbre. Les lépilémurs étaient communs dans cinq sites d'inventaire nocturne. Ils semblaient aussi abondants à la périphérie qu'à l'intérieur de la forêt. Leur densité variait de 67 à 154 ind./km² en 2016 et 72 à 179 ind./km² en 2017 (Tableau 3).

ÉVOLUTION DE LA DENSITÉ APPROXIMATIVE DES LÉMURIENS. La densité de *Propithecus deckenii*, *Hapalemur griseus ranomafanensis* et *Cheirogaleus medius* en 2016–2017 était bien plus élevée qu'en 1998 (Tableau 4). Celle de *P. deckenii* est passée de 98 ind./km² en 1998 à 170 ind./km2 en 2017. Par contre, la densité des *Eulemur rufus* qui était de près de 130 ind./km² en 1998 est tombée à seulement 2 ind./km² en 2017. Celle de *Lepilemur* sp. est passée de 573 en 1998 à 100 ind./km² en 2016 puis à 120 ind./km² en 2017. Les densités des autres espèces comme *Mirza coquereli* et Phaner pallenscens ont fluctué mais avec une tendance à la stabilisation durant les années 2016 et 2017 même si elles restent inférieures à celles de 1998. Les populations de toutes les espèces hormis *E. rufus* ont légèrement augmenté entre 2016 et 2017.

DISCUSSION

DIVERSITÉ SPÉCIFIQUE. Les résultats de cette recherche sont conformes à ceux de l'inventaire établi antérieurement (Ausilio et Raveloanrinoro 1998, Randriamanantena et al. 2019) si ce n'est que la taxinomie a été révisée depuis et que certaines

Tableau 4. Densité estimée en ind./km² (min–max) de chaque espèce de lémurien en 1998, 2015, 2016 et 2017. (†Ausilio et Raveloanrinoro 1998, §Randriamanantena et al. 2019)

Espèces	Années 1998†	2015§	2016	2017
Propithecus deckenii	98 (44–115)	148 (66–261)	151 (19–296)	170 (87–297)
Eulemur rufus	137 (24–427)	35 (0–83)	33 (0–111)	2 (0–13)
Hapalemur griseus ranomafanensis	présente	1	2 (0–11)	8 (0–45)
Microcebus sp.	288 (46–688)	455 (153–961)	331 (113–673)	364 (148–542)
Mirza coquereli	99 (0–307)	46 (0–153)	54 (10–75)	77 (20–151)
Cheirogaleus medius	présente	82 (0–270)	106 (68–154)	144 (107–195)
Phaner pallescens	426 (150–1071)	576 (153–1384)	278 (13–730)	305 (82–575)
Lepilemur sp.	573 (263–1250)	214 (173–269)	100 (67–154)	125 (72–179)

espèces ont été reclassées (Andriaholinirina et al. 2006, Tattersall 2007).

Pendant cette étude, l'identification spécifique des genres *Microcebus* et *Lepilemur* a posé un problème. En se basant sur la littérature, l'Aire Protégée Complexe Tsimembo Manambolomaty pourrait abriter *M. murinus* et *M. myoxinus* (Ausilio et Raveloanrinoro 1998, Rasoloarison et al. 2000). D'après d'autres recherches, *Microcebus myoxinus* aurait un pelage roux plus foncé que *M. murinus* (Schmid et Kappeler 1994, Rasoloarison et al. 2000) alors que la variation observée sur le terrain n'a pas permis d'identifier ces deux espèces de manière certaine sur le terrain sur la seule base de l'observation à l'œil nu. La détermination de la couleur du pelage devrait donc suivre le guide de Smithe (1975). Ce guide standardisé sous la lumière naturelle du jour est plus précis pour la détermination des couleurs que les photos qui peuvent faire varier la nuance.

Si Ausilio et Raveloanrinoro (1998) avaient déjà signalé des variations de couleur sur les Lépilémurs de la forêt de Tsimembo, les résultats de cette étude n'ont pas permis d'identifier ces animaux à l'espèce d'autant que la couleur n'est pas un caractère de distinction fiable pour le genre *Lepilemur*, car elle est variable en fonction de l'âge de chaque individu et des conditions lumineuses durant l'observation (Andriaholinirina et al. 2006). En plus, la répartition géographique du genre *Lepilemur* a été longuement controversée, même avec des analyses bio-géographiques (Zaramody et al. 2005, Ganzhorn et al. 2006). D'une part, diverses recherches avancent l'hypothèse que les rivières Tsiribihina ou Manambolo constitueraient une barrière pour *L. ruficaudatus* qui ne se trouverait pas dans la forêt de Tsimembo (Petter et al. 1977, Ishak et al. 1992). *L. randrianosoloi*, qui a été séparé de L. edwardsi en 2006 (Louis et al. 2006) est sympatrique avec une autre espèce à décrire dans cette localité au nord de la rivière Tsiribihina (Tomiuk et al. 1997, Bachmann et al. 2000). Seule, l'étude cytogénétique pourra confirmer et identifier les espèces qui y résident exactement.

La présence de *Daubentonia madagascariensis* ou Aye-aye annoncé par Sterling (1998) n'a pas été vérifiée. Aucun nid ou trace d'activité n'a été observé pendant cette étude. Toutefois, quelques habitants du village de Soatàna ont dit connaitre l'Aye-aye qu'ils appellent *Bekapaky*. Ils témoignent avoir vu un individu mort emporté par deux hommes dans un sac en 2009. Les deux hommes étaient passés par le village et auraient demandé quelques pièces d'argent aux curieux qui auraient voulu voir l'animal. Deux rencontres avec cette espèce ont également été enregistrées à Ambalamanga et à l'entrée de la forêt à Bemolaka en 2003 (Comm. pers). Ces localités se trouvent toutes dans l'Aire Protégée Complexe Tsimembo Manambolomaty. Il est donc nécessaire d'étendre les recherches de cette espèce dans d'autres sites de la forêt, dans la mesure où Ambondromifindra est exclue des observations nocturnes à cause d'un couvre-feu instauré dans le village d'Antseranandaka. Des visites à Marobanty qui se situe plus à l'intérieur ou à Ambaratamalinika à l'extrême Est de la forêt de Tsimembo, permettrait peut-être d'inventorier cette espèce dans le futur. La recherche des traces d'activités près des villages est recommandée car *D. madagascariensis* est fréquemment rencontrée dans des forêts près des habitations humaines (Sefczek et al. 2018).

DENSITÉ APPROXIMATIVE DES LÉMURIENS. Pour les lémuriens diurnes de la forêt de Tsimembo, les densités des populations d'*Hapalemur griseus ranomafanensis* et d'*Eulemur rufus* semblaient faibles. *H. griseus ranomafanensis* présente une écologie un peu particulière pour se nourrir et se reproduire, avec une distribution dans les forêts sèches liées à la présence de bambou *Viky*. Les recherches menées dans ces zones ont permis d'observer certains groupes composés d'adultes et de quelques individus immatures de deux générations successives.

La diminution de la densité des *Eulemur rufus* pourrait être la conséquence des pressions que l'espèce a subie. La chasse de cette espèce par les populations riveraines pour la consommation avait déjà été relevée dans les années 1990 (Bousquet et Rabetaliana 1992, Ausilio et Raveloanrinoro 1998). Au cours de notre étude, l'effet de la chasse active a été estimé par le comportement des *Eulemur rufus* qui étaient farouches et restait discrets avant de fuir les observateurs. Des pièges pour cibler cette espèce ont également été aperçus à quelques reprises.

Contrairement aux deux autres espèces de lémurien diurnes, *Propithecus deckenii* est abondante et a été rencontrée dans tous les sites visités. Et sa densité reste relativement élevée même à la périphérie de la forêt. Elle semble tolérer l'effet de bordure, contrairement à *P. coquereli* distribué au nord-ouest de Madagascar (McGoogan 2011). Toutefois, un suivi périodique serait nécessaire pour appuyer l'étude déjà réalisée sur la population de *P. deckenii* dans la forêt de Tsimembo (Razanantsoa 2000).

La densité de la plupart des espèces de lémuriens nocturnes est élevée. Certaines espèces telles que *Cheirogaleus medius*, *Lepilemur* sp. et *Microcebus* sp. sont abondantes même dans les sites qui se situent près des villages. Plusieurs recherches ont montré que certaines espèces sont sensibles au moindre changement de leur habitat, tandis que d'autres arrivent à s'adapter dans des milieux perturbés avec une formation secondaire. Dans la forêt de Kirindy, *M. murinus* est connue comme espèce résiliente, contrairement à *C. medius* qui fréquente rarement les zones perturbées (Rakotoniaina et al. 2016). Tant que subsistera un doute sur la présence d'une ou de deux espèces dans chacun des genres *Lepilemur* et *Microcebus*, les analyses sur l'abondance de ces populations demeureront au genre. Certaines espèces peuvent être cryptiques, ce qui influence fortement l'estimation de la densité (Besnard et Salles 2010).

ÉVOLUTION DE LA DENSITÉ DES LÉMURIENS. La densité de la plupart des espèces de lémuriens de l'Aire Protégée Complexe Tsimembo Manambolomaty a légèrement augmenté entre 2016 et 2017. La réduction de la densité des populations de *Eulemur rufus*, *Mirza coquereli*, *Phaner pallescens* et *Lepilemur* en 2017 par rapport à celles de 1998 peut-être l'effet de plusieurs facteurs dont la disparition de l'habitat, la chasse et le braconnage, les catastrophes naturelles et la disponibilité des ressources qui ont tous une influence sur la dynamique des population d'une espèce.

La méthode d'estimation de la densité en utilisant la moyenne des distances perpendiculaires au transect des individus est toujours sujette à discussions (Marshall et al. 2008, Besnard et Salles 2010, Ferrari et al. 2010) car elle a tendance à surestimer la densité (Meyler et al. 2012, Kun-Rodrigues et al. 2014). L'utilisation d'outils électroniques tels que les télémètres laser qui facilitent grandement la mesure de distance sur le terrain est donc recommandée (Triplet 2009, Besnard et Salles 2010). Néanmoins, les valeurs de la densité obtenues montrent une certaine harmonie avec ceux d'Ausilio et Raveloanrinoro (1998) et Randriamanantena et al. (2019).

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Assessing poverty and the relative importance of small-scale lobster fishing activity in coastal communities, southeast Madagascar

Jessica C. Savage, Sylvestre M. Randrianantenaina[1], Andrew Turner[1], Annelin Verkade[1], Allison B. DeVries[1], Quinn M. Parker[1], Stephen Long[2]

Correspondence:
SEED Madagascar
Fort Dauphin
Madagascar
Email: jessicacsavage1@gmail.com

ABSTRACT

Over 1.3 billion people worldwide are living in multidimensional poverty, where income and access to critical goods, services and utilities is limited. A lack of reliable, accessible, and resource-efficient methods of measuring poverty is a barrier to assessing the effectiveness of conservation and development initiatives designed to alleviate poverty and promote prosperity. This study employed the Basic Necessities Survey (BNS) as a context-specific tool for measuring multidimensional poverty. The approach produces a BNS score based on the level of access to assets (e.g., cooking equipment) and services (e.g., access to a doctor) that are locally considered basic necessities. The BNS was applied in southeast Madagascar to assess levels of prosperity in six coastal communities and gain insights into the relative importance of lobster fishing as an economic activity. All households surveyed (n=533) were found to be below the context-specific poverty line, with most households lacking access to multiple basic assets and services. Across all six communities, households engaged in the lobster fishery were found to be experiencing significantly lower levels of poverty, demonstrating the socio-economic importance of this fishery. Poverty levels were similar between communities, despite differences in non-governmental organisation (NGO) interventions and community-based fishery management, with the exception of one community experiencing significantly higher levels of poverty. The findings demonstrate the pervasive nature of poverty and deprivation in this region and have implications for ongoing efforts to promote sustainable management of marine resources. The BNS survey was found to be a resource-efficient tool, capable of measuring multidimensional poverty in a context-specific manner to support comparison within and between communities. The study demonstrates the BNS approach is an accessible and powerful tool for conservation and development practitioners. It is a nuanced measure of multidimensional poverty in communities, providing a means to monitor the impact of conservation and development interventions.

RÉSUMÉ

Plus de 1,3 milliard de personnes dans le monde vivent dans une pauvreté multidimensionnelle, où les revenus et l'accès aux biens, services et services essentiels sont limités. Le manque de méthodes fiables, accessibles et économes en ressources pour mesurer la pauvreté est un obstacle à l'évaluation de l'efficacité des initiatives de conservation et de développement conçues pour réduire la pauvreté et promouvoir la prospérité. Cette étude a utilisé l'enquête sur les besoins de base (BNS) comme outil spécifique au contexte pour mesurer la pauvreté multidimensionnelle. L'approche produit un score BNS basé sur le niveau d'accès aux biens (par exemple, le matériel de cuisine) et aux services (par exemple, l'accès à un médecin) qui sont localement considérés comme des nécessités de base. Le BNS a été appliqué dans le sud-est de Madagascar pour évaluer les niveaux de prospérité dans six communautés côtières et mieux comprendre l'importance relative de la pêche au homard en tant qu'activité économique. Tous les ménages interrogés (n = 533) se trouvaient en dessous du seuil de pauvreté spécifique au contexte, la grande majorité des ménages n'ayant pas accès à plusieurs biens et services de base. Dans les six communautés, les ménages engagés dans la pêche au homard se sont avérés connaître des niveaux de pauvreté nettement inférieurs, démontrant l'importance socio-économique de cette pêche. Les niveaux de pauvreté étaient similaires entre les communautés, malgré les différences dans les interventions des organisations non gouvernementales (ONG) et la gestion communautaire des pêches, à l’exception d’une communauté connaissant des niveaux de pauvreté significativement plus élevés. Les résultats démontrent la nature omniprésente de la pauvreté et des privations dans cette région et ont des implications pour les efforts en cours visant à promouvoir la gestion durable des ressources marines. L'enquête BNS s'est avérée être un outil économe en ressources, capable de mesurer la pauvreté multidimensionnelle d'une manière spécifique au contexte pour soutenir la comparaison au sein et entre les communautés et entre elles. L'étude démontre que l'approche BNS est un outil ac-

1 SEED Madagascar, Fort Dauphin, Madagascar
2 Institute of Zoology, Zoological Society of London, UK

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cessible et puissant pour les praticiens de la conservation et du développement. Il s'agit d'une mesure nuancée de la pauvreté multidimensionnelle dans les communautés, offrant un moyen de surveiller l'impact des interventions de conservation et de développement.

INTRODUCTION

Despite significant progress, poverty remains widespread, with 600 million people living in extreme poverty below the international poverty line of US$1.90 purchasing power parity (PPP) (UNDP 2019a,b). Recognising the multidimensional nature of poverty is a critical first step to addressing it effectively. This includes social, economic, and political deprivation, such as limited access to education, sanitation, healthcare, and basic utilities (World Bank 2018). The Multidimensional Poverty Index (MPI) finds some 1.3 billion people in low-income countries are multidimensionally poor (UNDP 2019a). Sustainable Development Goal (SDG) 1 aims to "end poverty in all its forms everywhere" by 2030 (UN 2015), reflecting its intrinsic link with other SDGs and broader conservation and development objectives globally.

Designing and monitoring local conservation and development interventions requires understanding and tracking of poverty levels (Haughton and Khandker 2009). However, the multidimensional nature of poverty means it is challenging to define, let alone measure (Bibi 2005, Robeyns 2005, Flechtner 2021). Various well-established approaches exist, such as the MPI (Alkire and Santos 2014), but no single measure is universally optimal (Bibi 2005, Haughton and Khandker 2009). Established approaches are often impractical for practitioners, as they are expensive, time-consuming, require technical expertise and are not tailored to local contexts (Wilkie et al. 2015).

The Basic Necessities Survey (BNS) is a participatory approach to measuring poverty developed in 1997 and addresses some of these challenges (Davies and Smith 1998, Wilkie et al. 2015). The BNS employs a broad, practical definition of poverty as "a lack of basic necessities" (Davies and Smith 1998: 3). In contrast to defined poverty lines, there is no a priori definition of what basic necessities are (Davies and Smith 1998). Instead, the BNS assesses poverty based on local perceptions of basic necessities, thus ensuring relevance to the local context (Wilkie et al. 2015). Households that do not own or have access to all items considered basic necessities are regarded as being below the locally defined poverty line. The BNS approach is comparatively quick, inexpensive and does not require specialist skills (Wilkie et al. 2015). It has been used to assess the socio-economic impacts of conservation initiatives, e.g., effects of terrestrial protected areas (Clements et al. 2014, Wei and Yali 2017, Beauchamp et al. 2018). The BNS has principally been used by NGOs (Davies and Smith 1998, Davies 2006, Clements and Milner-Gulland 2015) but has received only limited attention in the academic literature (Wilkie et al. 2015) and has not been applied to coastal communities dependent on marine resources.

Small-scale fisheries (SSFs) employ the vast majority of the world's fishers (Béné et al. 2007) and support an estimated 492 million people globally (FAO 2022). SSFs can alleviate poverty by contributing to food security, providing livelihoods, and supporting economies (Andrew et al. 2007). Consequently, the sustainable management of SSFs is subject to global commitments including SDG 14, Life Below Water, and Aichi Biodiversity Target 11 (CBD 2010, UN 2015). Community Based Natural Resource Management approaches and Locally Managed Marine Areas (LMMAs) have increasingly been employed to improve the sustainability of SSFs. Their effectiveness has been repeatedly demonstrated (Christie and White 1997, Wamukota et al. 2012) though some studies have highlighted the limitations and challenges of bottom-up approaches to marine resource governance (Jones and Long 2021, Parker et al. 2024). LMMAs in particular have proliferated, with numerous well-established examples in the Indo-Pacific (Cinner et al. 2005, Jupiter et al. 2014, Rocliffe et al. 2014) and more recently in Madagascar (Harris 2011, Mayol 2013).

Madagascar is one of the world's least developed countries, being 164 out of 189 countries on the Human Development Index (HDI) (UNDP 2020) and failing to achieve a single Millennium Development Goal (Waeber et al. 2016). Nearly eight in ten people (77.6%) live below the international poverty line of $1.90 PPP, and, more than half of the population (57.1%) experience severe multidimensional poverty (UNDP 2020). The majority of the country's 27.7 million people (UNDESA 2020) live within 100km of the 5,500km coastline (EarthTrends 2003, Harris 2011). Accordingly, SSFs are critically important for food security, nutrition, livelihoods, and the economy (Le Manach et al. 2012, Barnes-Mauthe et al. 2013), with at least 100,000 fishers involved in SSFs (Le Manach et al. 2011). However, landings from SSFs have peaked and many fisheries are in decline (Sáenz-Arroyo et al. 2005, Le Manach et al. 2012, World Bank 2015). In response, Madagascar has committed to the Aichi Biodiversity Targets, aiming to conserve 15% of marine and coastal areas (Rabarison et al. 2016) in addition to its 2014 pledge to triple marine protected area coverage within 10 years (speech presented at the VIth World Parks Congress in Sydney by Hery Rajaonarimampianina, President of Madagascar). Concurrently, there has been a proliferation of LMMAs, with over 170 now spanning approximately 17,270km² (MIHARI 2020).

Madagascar's southern regions (Atsimo Andrefana, Androy, and Anosy) are home to 12% of the country's population (Healy 2018) and are the poorest part of the country, where 91% of the largely rural population live below the $1.90 PPP international poverty line (Healy 2018). Communities here are subject to multiple forms of deprivation including insufficient access to clean water, food insecurity and malnutrition, and high levels of child mortality (Healy 2018, European Commission 2021). These challenges are compounded in coastal communities, where few viable livelihoods exist due to a lack of access to education, transport infrastructure and suitable agricultural land (Healy 2018). The regional fishery for spiny lobsters has few barriers to entry, consequently, many coastal communities depend on this high-value export commodity for livelihoods, which contributes significantly to the regional economy (Long 2017, Long et al. 2021). The fishery consists of approximately 40 coastal communities in the Androy and Anosy regions, employing an estimated 15,000 people (MAEP 2004) and accounts for the majority of Madagascar's annual lobster catch and export (Sabatini et al. 2008). The limited available evidence suggests that the regional stock is in decline, following increased fishing pressure driven by population growth and high export demand (Long 2017, Sabatini et al. 2008, Holloway and Short 2014).

Since 2013, Project Oratsimba, led by British NGO SEED Madagascar (henceforth SEED), has sought to establish a replicable model for sustainable, community-based lobster fishery management in three communities, whilst promoting prosperity (Azafady 2014, Skinner et al. 2016, Darwin Intiative 2018). This has included the introduction of periodic No Take Zones (Long 2017) and establishing the 160km² Sainte Luce LMMA (Long et al. 2021). A barrier to effectively implementing and assessing this project, is a lack of detailed understanding of poverty within the target communities and the relative economic importance of marine resources.

This study uses the BNS to assess the prevalence of poverty within six coastal communities in southeast Madagascar, focussing on the relative importance of lobster fishing to household poverty alleviation. It evaluates the BNS approach as a practical methodology for resource-constrained organizations to measure poverty. The findings are intended to have direct applications for the management of marine and other natural resources and provide a reference point for assessing changes in household prosperity in relation to fisheries management interventions.

METHODS

The data presented here were collected as part of a larger survey undertaken during Project Oratsimba Phase III (Darwin Intiative 2018). The full survey methodology is described by Savage (2020a). Here, only the components of the survey relevant to the data presented in this study are described, the survey is provided in the supplementary material. Prior to research, permission was granted by the Direction Régional de l'Agriculture, de l'Élevage et de la Pêche (Regional Directorate of Agriculture, Livestock and Fisheries) and the *Chef Fokontany* (community elected leader) in each of the communities surveyed. Due to low levels of literacy, full informed consent was obtained verbally from participants in the presence of at least two members of the survey team. Participants were informed that participation was voluntary and were given the opportunity to ask questions. This study was undertaken in accordance with SEED's Human Research Code of Ethics.

STUDY SITE. Data were collected from six coastal communities, each consisting of one or more hamlets, in the Anosy region, southeast Madagascar (Figure 1). One community (Baie d'Italie) is located 30 km south of the regional capital Fort-Dauphin and the other communities are within 60 km north of Fort Dauphin (Taolagnaro). Three of these communities (Sainte Luce, Elodrato, Itapera) were intended beneficiaries of Project Oratsimba and have been subject to efforts to establish community-based lobster fishery management. The other three communities (Ambanihazo, Antsotso, Baie d'Italie) were selected for comparative purposes as they have not been subject to any externally supported community-based fisheries management initiatives. Prior to selection, the six communities were visited to confirm they were broadly similar in terms of size and demographics and thus suitable for comparison. The six communities are briefly characterised below, noting any socio-economic features, they are presented in order from north to south.

Antsotso. Antsotso is located next to the Route Nationale 12 (RN12) and consists of 12 small hamlets, at least six of which were identified as involved in lobster fishing by the *Chef Fokontany*. Maximum travel time to the fishery landing site is 1.5 hours by foot and canoe. None of the hamlets making up Antsotso are located at the landing site. Antsotso has had no previous experience with community-based fisheries management, although the community is aware of fisheries management measures in Sainte Luce. However, the community has had support from various NGOs in the past including a sea turtle conservation project in 2001–2002 led by SEED; the provision of education, water, and sanitation infrastructure by UNICEF; and forest conservation initiatives led by Asity Madagascar.

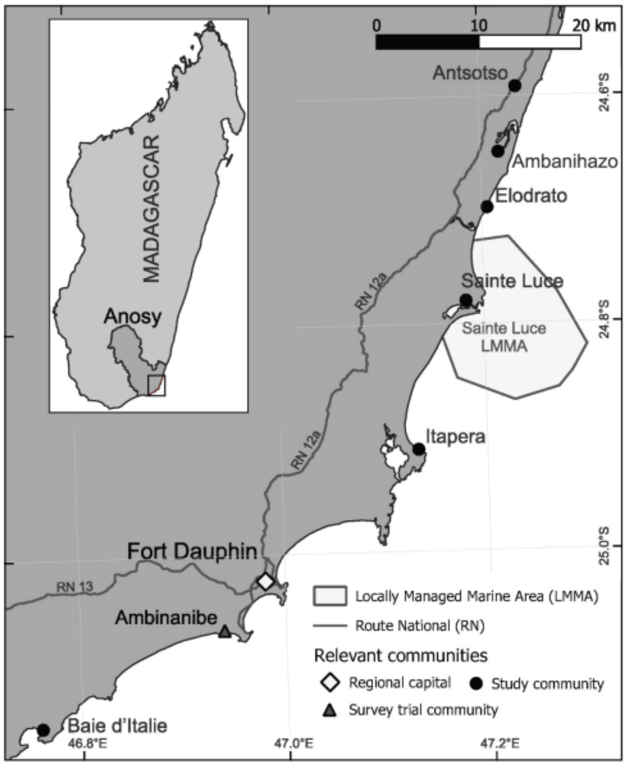

Figure 1. Study area showing relevant communities, major roads (Routes Nationales) and the Sainte Luce Locally Managed Marine Area (LMMA). (For graphical clarity watercourses, minor roads and constitute hamlets of study communities are not shown. Inset locator map shows Anosy region within Madagascar and the coverage of main map)

Ambanihazo. Ambanihazo is located along the Voendry river and the RN12, and consists of 11 small hamlets, with seven of these identified as involved in lobster fishing by the *Chef Fokontany*. Recent house fires in the largest hamlet in Ambanihazo, led the community to disperse and rebuild in several smaller hamlets. Maximum travel time to the landing site is two hours by foot and canoe. It is understood that the community tried to establish their own No Take Zone in 2015 driven by their perception of successes in Sainte Luce. The management measures introduced by the community reportedly did not persist due to a lack of community cooperation, an absence of external support (financial and technical) and difficulties with peer enforcement, replicating the enforcement model in Sainte Luce (Long 2017).

Elodrato. Elodrato was originally a farming community; however, cultural exchange and migration from Sainte Luce brought lobster fishing to this community (SEED Madagascar 2018). Fishers from five hamlets (Ebakika North, Ebakika South, Esohihy North, Esohihy South and Elodrato) use the same landing site (in Elodrato) and fishing grounds. For the purpose of fisheries management and this study, they are considered one fishing community, 'Elodrato'. Three of the hamlets are located along RN 12, whilst two are only accessible by foot. Travel time to the landing site from Ebakika South, the furthest of these five hamlets from the coast, is two hours by foot and canoe. Following the successes observed in Sainte Luce, Elodrato established their own No Take Zone in 2014 (Long 2017). However, the No Take Zone ceased operation due to a lack of formal governance structures and NGO support. In 2016 during Phase II, Project Oratsimba began informally supporting this community (Skinner et al. 2016). In 2018, Elodrato was formally incorporated into Project Oratsimba Phase III. At the time of this study, the beginning of Phase III, support focussed on forming the necessary conditions for LMMA establishment through meetings with the *Chef Fokontany* and community and formation of a fisher's association. The surfacing of sections of road immediately north of Elodrato has been an ongoing source of employment and income for this community since 2015 (SEED Madagascar 2018).

Sainte Luce. Sainte Luce is the focal point of lobster fishing in the southeast (Sabatini et al. 2008). It is believed locally that lobster fishing in Anosy originated here in the 1960s (Charbonnier and Crosner 1961). Sainte Luce is comprised of three hamlets, with the largest located adjacent to the beach which serves as the principal landing site. SEED has been working with the community since 2000 on various conservation, health, and sustainable livelihoods projects. Since 2013, this has included Project Oratsimba, which was initiated in response to widespread community perceptions of declining lobster catches and resultant decreases in household income (Holloway and Short 2014). The project has supported the community to establish an LMMA with a periodic No Take Zone as the primary management measure, which has been operational since 2014. A detailed analysis of the governance of the LMMA is provided by Long et al. (2021). Short-term increases in catch per unit effort and the price fishers received were associated with No Take Zone openings (Long 2017). NGO (SEED) related activities and a luxury eco-lodge (which subsequently ceased operation in 2020) provide employment opportunities in this community. QMM (QIT Madagascar Minerals, a subsidiary of Rio Tinto) holds mining rights for areas adjacent to this community, with the intention of undertaking ilmenite mining here in the future (Smith et al. 2012, Hyde Roberts 2023). Exploration, planning, and mitigation activities associated with this have provided limited local employment (Holloway and Short 2014) and resulted in the introduction of protected areas of littoral forest (Temple et al. 2012). Community perceptions of the effects of mining activities in the region are largely negative (Zaehringer et al. 2024).

Itapera. Lobster fishing in Itapera is also thought to have begun in the 1960s (Charbonnier and Crosner 1961). Itapera consists of a single hamlet located on the coast at the landing site. Although located closest to Fort Dauphin, the community is somewhat isolated, as no part of it can be directly accessed by car. Itapera has a high proportion of migrant fishers from southwest Madagascar, of the Vezo ethnicity, who have been present since at least 2001 and possibly since the 1970s (SEED Madagascar 2018). The migrant fishers initially used free diving and gill nets targeting sharks and turtles. The settled migrant fishers have since become involved in lobster fishing, and this has caused ongoing tensions with residents about different fishing gear usage and access to fishing grounds. Itapera was also previously subjected to efforts to establish a marine protected area through the World Bank funded Projet Pôles Intégrés de Croissance (Integrated Growth Poles Project) (IAP 2014). Our understanding is this project was unsuccessful as the top-down approach was not widely accepted by the community. Similar to Elodrato, the success observed in Sainte Luce also catalysed the community to establish their own NTZ (Long 2017) and in 2016 Project Oratsimba Phase II began informally supporting the community (Skinner et al. 2016). In 2018, Itapera was formally incorporated into Project Oratsimba Phase III. A lack of cooperation within the community and mistrust of outsiders have been barriers to implementing any community-based fishery management measures with NGO support (Antilahy et al. 2020, Savage 2020b).

Baie d'Italie. Baie d'Italie is the only community surveyed located south of Fort Dauphin and consists of one hamlet located on the beach, which serves as the fishery's landing site. Despite the proximity to Fort Dauphin, this community is relatively isolated as unmaintained roads mean the community is not easily accessible by vehicle. The community has had no previous experience with community-based fishery management. This community has the least infrastructure in terms of health and education. Community members report this community receives little or no external support, from the state, NGOs, or similar.

SURVEY METHODOLOGY. The survey was conducted in January–March 2019. Prior to this, the survey was trialled in Ambinanibe, a small-scale lobster fishing community on the outskirts of Fort Dauphin, which has an established LMMA supported by NGO Aquatic Service. The trial survey was conducted with eight households to evaluate the suitability of the survey questions and refine the methodology. The survey was conducted in Malagasy, by translators with prior experience conducting socio-economic surveys in the region, ensuring functional translation from Malagasy to English. Data were recorded in English by SEED staff on smartphones (Android operating system) using the ODK Collect application (version 1.18.2, Hartung et al. 2010). The survey participant representing each household was the self-identified head of the household when available. Otherwise, another adult from the household who was present participated. Survey participants were asked questions to provide basic demographic information, details about livelihoods, and information needed to estimate poverty, using the BNS approach.

Sampling approach. The total survey hours were approximately evenly distributed among the lobster fishing hamlets within each of the six communities. Hamlets identified by the *Chef Fokontany* as not involved in lobster fishing were not surveyed, in line with the study's scope. Households were selected using a spinner to determine the travel direction and dice to determine the travel distance (in terms of the number of houses) to approximate randomness, starting from the centre of each hamlet. To control against the timing of gender specific activities and minimise gender bias, surveys were conducted from approximately 07:00 to 18:00. The sampling sought to ensure a similarly representative sample size from each community with a minimum of 10% of households in each community sampled. Beyond this threshold, the actual number of surveys conducted depended on the number of households available, travel time between hamlets, and events occurring within the communities.

Demographic data collection. Estimates of the population size for each community were obtained from the *Chef Fokontany*. Participants were asked to provide the total number of people living in their household along with the gender and ages of each member. Additionally, participants were asked if they were the head of the household, how many years of formal education they had received, and whether they were an active lobster fisher.

Livelihood data collection. Each household surveyed was asked to list all the livelihood activities that generated income for their household, specifically excluding activities solely for subsistence. Participants were then asked to rank the first and second most important activity in terms of household income. Following completion of the survey, the reported activities were standardised into nine groups of income-generating activities. This allowed the calculation of the mean number of income-generating activities per household. Participants were also explicitly asked about household participation in extractive resource use of conservation concern (shark fishing, non-subsistence production/sale of charcoal, firewood or timber, mosquito net fishing and, bushmeat consumption).

Modified Basic Necessities Survey. In November and December 2018, before conducting the household surveys, two focus groups were held in each of the six communities, divided by gender. Participants were selected to represent a range of ages and household wealth. These focus groups were asked to identify potential basic necessities (assets and services), defined as "something all families should have and no family should live without" (Wilkie et al. 2015: 31). The resulting list contained 33 potential basic necessities, of which 29 were assets and four were services, which was then used in the household surveys, see supplementary material.

During each household survey, participants were shown picture cards representing each of the potential basic necessities in a random order. Picture cards were not used for services, which were instead verbally described. Participants were first asked if their household owned or had access to the item. They were then asked whether they considered the item a basic necessity in their community, i.e., whether it was something "all families should have and no family should live without" (Wilkie et al. 2015: 31).

The BNS score 'S' for each household was calculated per Equation 1:

$$S=\left(\frac{\sum(A\times B)}{\sum A}\right)\times 100$$

Where, any item that was identified as a basic necessity by less than 50% of households surveyed was excluded from the BNS score calculation i.e., not deemed a basic necessity. For each of the remaining items: i) a weighting 'A' was determined as the proportion of households identifying the item as a basic necessity; and ii) a binary score 'B' (one or zero) was given, according to whether they did or did not have access/ownership.

BNS scores can range from 0% to 100%. A score of 0% indicates a household experiencing extreme poverty, lacking access to or ownership of any basic necessities. In contrast, a score of 100% represents a household at or above the locally defined poverty line, with access to or ownership of all of the basic necessities (Wilkie et al. 2015). A diagrammatic overview of the BNS methodology is provided in the supplementary material.

STATISTICAL ANALYSIS. If participants were unable or chose not to provide an answer, those responses were excluded from the relevant analysis, which is reflected in reported sample size. Statistical analysis was performed in R version 3.6.2 (R Core Team 2020). Household BNS score was modelled using Generalised Linear Models (GLM) employing lobster fishing status (categorical, two levels) and community (categorical, six levels) as explanatory variables. The full model included both explanatory variables and the interaction between them. Stepwise model simplification was conducted using F-tests to determine the significance of dropped terms to produce a minimum adequate model. The resulting model contained both lobster fishing status and community. Post-hoc pairwise comparisons between variable levels were conducted using Tukey's test.

RESULTS

DEMOGRAPHIC DATA. A total of 553 households were surveyed. Household demographics in the communities were similar with regards to the proportion of the population below the age of 18 and over the age 65 and, the household size (Table 1). Notably, across all communities, household size was consistently larger in lobster fishing households compared to non-fishing households. There was some variation in the ages of survey participants representing each household, though median age was similar across communities. The level of education among survey participants was similar between communities, with the exception of Baie d'Italie, where nearly half of participants (48.5%) had no formal education.

INCOME-GENERATING ACTIVITY DATA. Lobster fishery-related activities (fishing or buying) were the most commonly practiced primary income-generating activity in all six communities. These activities were practiced by more than 50% of households in every community except for Elodrato (Figure 2). Eight households reported no participation in any income-generating activities, and 41 households reported relying on only one activity.

Most households participated in more than one income-generating activity, with the mean number of activities per household being 3.2 (± 1.3). The mean number of income-generating activities was higher for lobster fishing households (3.6 ± 1.1) compared to non-fishing households (2.1 ± 1.1), a trend observed across all communities (Table 2). In Baie d'Italie, Itapera, and Sainte Luce, fishing for other marine species was the most common secondary income-generating activity, practiced by more than 50% of households. In contrast, households in Ambanihazo, Antsotso, and Elodrato engaged in a more diverse range of secondary income-generating activities (Figure 3).

EXTRACTIVE RESOURCE USE OF CONSERVATION CONCERN. Of households surveyed, 69.3% participated in one or more extractive resource activities of conservation concern. In each community fishing for, or selling, shark fins and meat was the most widely practiced extractive resource activity of conservation concern and bushmeat hunting the least (Table 2).

BASIC NECESSITIES SURVEY DATA. A total of 22 items, out of an initial list of 33, were identified as basic necessities (by more than 50% of surveyed households). No household owned or had access to all 22 basic necessity items (Table 3). Therefore, all households had a BNS score less than 100.0% and can be considered as living below the locally defined poverty line. The vast majority of households, 87.3%, had a BNS score below 75.0% and were considered to be far from the locally defined poverty line, experiencing severe poverty. Mean household BNS score of all households surveyed was 60.3% (Table 4). In all communities, lobster fishing households had a significantly higher BNS score and thus were experiencing less severe poverty compared to non-fishing households ($F_{1,547}$=42.9, p<0.001). BNS score also varied significantly between communities ($F_{5,551}$=,11.5, p<0.001) (Figure 4). A post hoc Tukey test demonstrated that Baie d'Italie had a significantly lower BNS score compared to all other communities (p<0.05) and Itapera had a significantly lower BNS score compared to Sainte Luce (p<0.05). BNS score comparisons between the other four communities did not differ significantly (p>0.05).

Table 1. Demographic data from the household survey, disaggregated by community. (Amb = Ambanihazo, Ant = Antsotso, BdI = Baie d'Italie, Elo = Elodrato, Ita = Itapera and StL = Sainte Luce; means are presented (± standard deviation); the sample size was n=533, unless otherwise stated; * As provided by the *Chef Fokontany* in each community; † Estimated from the ages reported at the household level; ‡ Includes participants with no years of formal education)

	Amb	Ant	BdI	Elo	Ita	StL	ALL
Community-level							
Population*	2400	1500	1300	4200	1600	4800	15,800
Households surveyed	82	98	102	95	74	102	553
Est. population <18 (%)†	41.2	46.3	50.9	44.3	53.2	42.4	46.5
Est. population ≥ 65 (%)†	6.0	2.2	1.9	2.5	2.5	2.5	2.8
Household-level							
Mean household size all	4.4 (1.8)	4.7 (2.2)	5.1 (2.0)	4.6 (2.2)	5.9 (2.2)	5.1 (2.1)	4.9 (2.1)
Mean household size fishing	4.8 (1.7)	4.9 (2.2)	5.3 (1.9)	5.0 (2.4)	5.9 (2.2)	5.2 (2.1)	5.2 (2.1)
Mean household size non-fishing	3.9 (1.9)	3.9 (2.0)	3.9 (2.6)	4.1 (1.9)	5.5 (2.3)	4.3 (2.2)	4.1 (2.1)
Mean number of children <18	1.8 (1.3)	2.2 (1.5)	2.6 (1.7)	2.0 (1.6)	3.1 (1.6)	2.1 (1.5)	2.3 (1.6)
Mean number of adults ≥65	0.3 (0.5)	0.1 (0.3)	0.1 (0.4)	0.1 (0.4)	0.1 (0.4)	0.1 (0.4)	0.1 (0.4)
Participant-level							
Median age, n=551	34.5	34.0	37.0	31.0	32.5	35.0	34.0
Head of household (%)	63.4	61.2	61.8	51.6	71.6	53.9	60
Female (%)	51.2	53.1	54.9	62.1	41.9	57.8	54.1
Active lobster fisher (%)	36.6	42.9	44.1	26.3	54.1	40.2	40.3
No formal education (%) n=549	24.4	18.6	48.5	22.3	25.7	14.9	25.9
Mean years of formal education, n=549 ‡	3.9 (3.3)	4.2 (3.2)	1.8 (2.2)	3.9 (3.3)	3.2 (2.8)	4.4 (2.8)	3.6 (3.1)

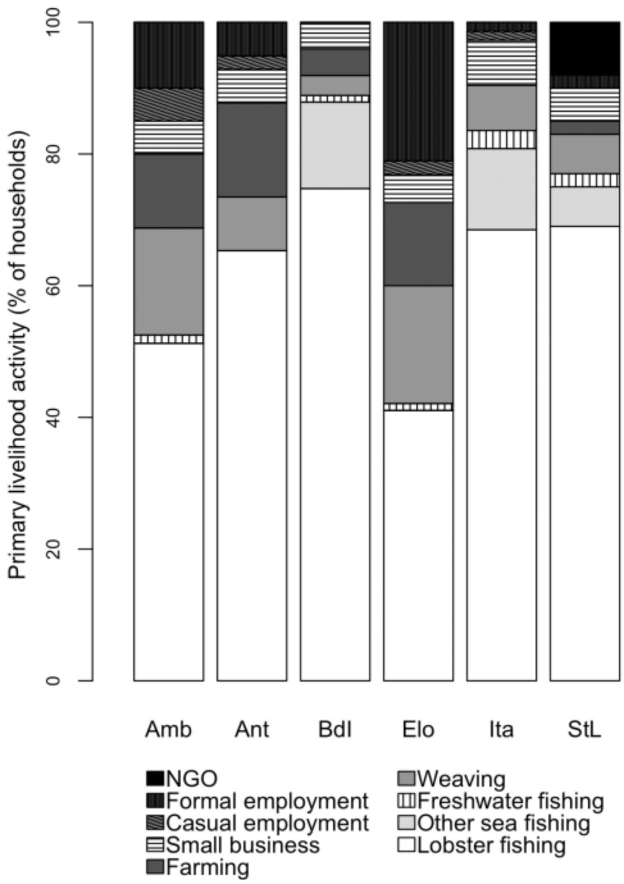

Figure 2. Primary income-generating activities of households disaggregated by community. (The category 'NGO' represents direct employment with NGOs and income gained through NGO initiatives such as selling products of women's co-operatives; household responses (n=545) were from: Amb = Ambanihazo, Ant = Antsotso, BdI = Baie d'Italie, Elo = Elodrato, Ita = Itapera and StL = Sainte Luce)

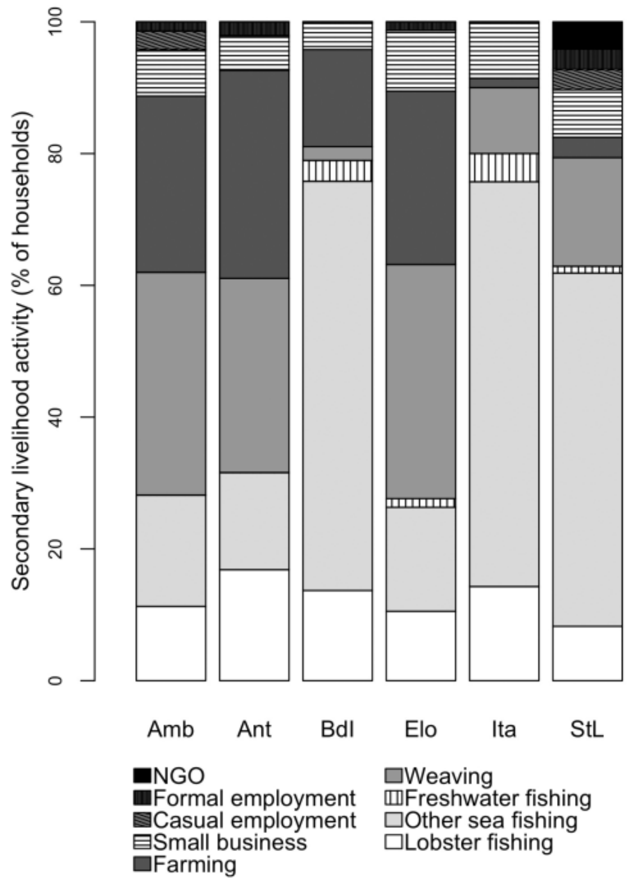

Figure 3. Secondary income-generating activity of households disaggregated by community. (The category 'NGO' represents direct employment with NGOs and income gained through NGO initiatives such as selling products of women's co-operatives; household responses (n=504) were from: Amb = Ambanihazo, Ant = Antsotso, BdI = Baie d'Italie, Elo = Elodrato, Ita = Itapera and StL = Sainte Luce)

Table 2. Number of income-generating activities and participation rates for extractive activities of conservation concern, at the household level, disaggregated by community (n=553 for: Amb = Ambanihazo, Ant = Antsotso, BdI = Baie d'Italie, Elo = Elodrato, Ita = Itapera and StL = Sainte Luce; means are presented (± standard deviation); * Primary purpose is for income generation; unsold catch will be used for subsistence; † Excludes for subsistence purposes)

	Amb	Ant	BdI	Elo	Ita	StL	ALL
Number of livelihoods							
Mean number of livelihood activities per household	2.9 (1.3)	3.4 (1.0)	3.1 (1.4)	2.9 (1.3)	3.7 (1.2)	3.3 (1.4)	3.2 (1.3)
Mean number of livelihood activities per lobster fishing household	3.5 (1.1)	3.6 (0.9)	3.3 (1.2)	3.7 (1.6)	3.9 (1.0)	3.6 (1.3)	3.6 (1.1)
Mean number of livelihood activities per non-fishing household	2.0 (1.0)	2.3 (0.8	1.5 (1.3)	2.0 (1.7)	2.4 (1.4)	2.1 (1.2)	2.1 (1.1)
Participation rates for extractive activities of conservation concern (% of households)							
Shark fishery*	36.6	61.2	66.7	33.7	52.7	59.8	52.4
Production/sale of charcoal, firewood or timber†	17.1	41.8	34.3	22.1	31.1	35.3	30.7
Fishing with mosquito net*	22	32.7	33.3	18.9	45.9	42.2	32.4
Bushmeat consumption	3.7	7.1	0	3.2	4.1	5.9	4
One or more activities of conservation concern	48.8	73.5	84.3	47.4	81.1	78.4	69.3

Table 3. The 22 basic necessities items identified by participants across all communities from an initial list of 33. (Items are ordered by frequency of identification as a necessity. The percentage of households which had access to, or ownership of each item is shown, disaggregated by community (n=553) for: Amb = Ambanihazo, Ant = Antsotso, BdI = Baie d'Italie, Elo = Elodrato, Ita = Itapera and StL = Sainte Luce; * Wooden lobster pots are commonly used as they are inexpensive and are handmade using locally available materials. In contrast metal lobster pots are used rarely for lobster fishing as they are expensive and not locally available and instead are used to store lobsters adjacent to the landing site prior to sale)

	Amb	Ant	BdI	Elo	Ita	StL	ALL
Metal spoon	100.0	99.0	100.0	98.9	98.6	99.0	99.3
Cooking pot for rice	100.0	100.0	97.1	98.9	100.0	98.0	98.9
Tin plate	100.0	96.9	98.0	98.9	100.0	99.0	98.7
Mahampy mat, hand woven reed mat	98.8	99.0	97.1	97.9	97.3	99.0	98.2
Metal cooking tripod	98.8	100.0	84.3	93.7	93.2	99.0	94.8
Plastic bucket	96.3	99.0	78.4	96.8	94.6	98.0	93.7
Shoes	95.1	92.9	91.2	91.6	90.5	95.1	92.8
Fleece blanket	91.5	89.8	38.2	88.4	81.1	88.2	78.8
Lobster pot (wooden)*	63.4	81.6	83.3	51.6	79.7	73.5	72.3
Bed	73.2	60.2	30.4	71.6	60.8	78.4	62.0
Water well or tap in the community	11.0	40.8	99.0	42.1	91.9	81.4	61.7
Glass cup	76.8	75.5	29.4	67.4	40.5	74.5	60.9
Zebu, dry adapted indicine cattle (*Bos indicus*)	75.6	54.1	43.1	50.5	20.3	29.4	45.6
Radio	36.6	27.6	18.6	42.1	39.2	47.1	34.9
Antanosy pirogue, wooden dugout canoe	37.8	19.4	36.3	13.7	16.2	40.2	27.7
Life jacket	11.0	14.3	14.7	7.4	10.8	63.7	21.3
Money to send all children to primary school	35.4	34.7	13.8	18.9	12.2	13.7	21.3
Large cooking pot for celebrations	23.2	20.4	15.7	28.4	12.2	24.5	21.0
Money to visit a doctor	17.1	26.5	5.9	26.3	24.3	16.7	19.2
Enough money to be able to save money	22.0	25.5	2.9	25.3	24.3	16.7	19.0
Lobster pot (metal)*	31.7	22.4	8.8	10.5	10.8	8.8	15.2
Household latrine	0.0	1.0	0.0	1.1	0.0	4.9	1.3

Table 4. Mean Basic Necessities Survey score disaggregated according to whether the household derives income from lobster fishing or not. (n=553 for: Amb = Ambanihazo, Ant = Antsotso, BdI = Baie d'Italie, Elo = Elodrato, Ita = Itapera and StL = Sainte Luce; means are presented (± standard deviation))

	Amb	Ant	BdI	Elo	Ita	StL	ALL
All households	62.4 (11.8)	62.4 (13.0)	54.0 (13.0)	59.4 (12.3)	59.1 (11.8)	64.6 (11.2)	60.3 (12.7)
Lobster fishing households	66.2 (9.2)	63.4 (12.3)	55.6 (12.7)	62.0 (11.2)	60.8 (11.4)	65.7 (10.9)	62.0 (12.0)
Non-fishing households	56.6 (13.0)	58.2 (15.2)	43.0 (8.7)	56.2 (12.9)	51.1 (10.7)	58.9 (11.1)	55.2 (13.1)

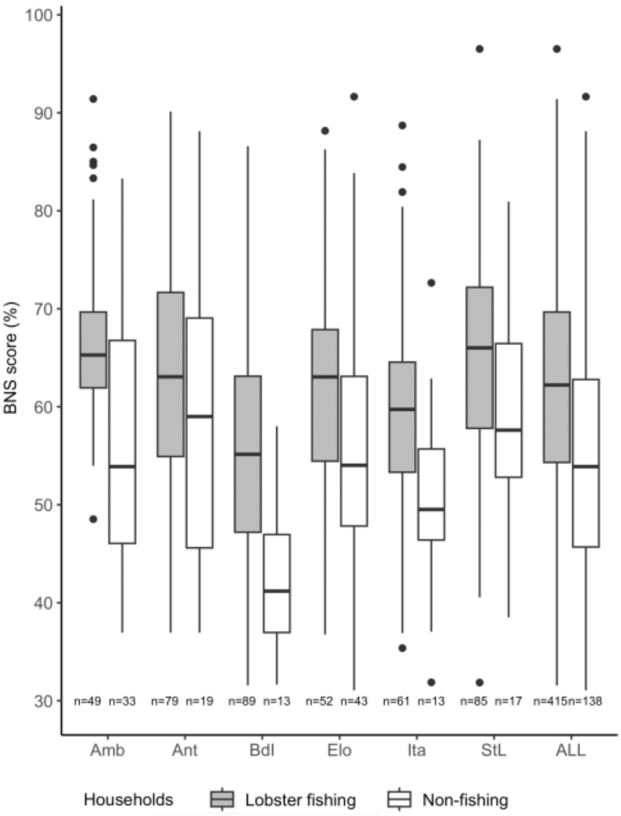

Figure 4. Boxplot showing the Basic Necessities Survey (BNS) score of households in six communities. (n=553 households disaggregated according to whether the household derives income from lobster fishing (grey) or not (white) for: Amb = Ambanihazo, Ant = Antsotso, BdI = Baie d'Italie, Elo = Elodrato, Ita = Itapera and StL = Sainte Luce; the median (thick line) interquartile range (IQR, filled box) are shown; the range is indicated by whiskers (thin line) extending no more than 1.5 times the IQR, values beyond this are considered outliers and are drawn (filled circles))

DISCUSSION

CHOICE OF TERMINOLOGY. A challenge in the preparation of this work was the choice of terminology. When using terminology surrounding poverty, there is a danger that well-intentioned work can reinforce, rather than address, prevailing narratives, and promote a narrow perspective (Thomas et al. 2020) i.e., presenting Madagascar as a place defined by poverty. Madagascar is a rich, complex, and varied nation with many opportunities and challenges. Poverty is a situation, and it is not a defining characteristic of Madagascar, nor of its people. It is also important to note that a key contributor to many of the challenges facing Madagascar, including poverty, is the colonisation of Madagascar, theft of generational wealth, economic exploitation, and attempted severance of Malagasy people from traditional resource use and cultural practices by colonising nations (Kull 2000, Scales 2011). This historical and contemporary context must be recognised when speaking about poverty as a condition.

Within this context, rather than eliminating poverty, as per SDG 1, a more positive goal would be to go beyond that and promote prosperity, as defined by the cultures and values of people within a given nation. For these reasons, where appropriate, the term prosperity is deliberately used, when referring to levels of wealth more broadly, whilst poverty is used when referring specifically to multi-dimensional poverty, including as defined and measured by the BNS methodology. Nevertheless, this study seeks to specifically measure poverty.

POVERTY ASSESSMENT. No household had a BNS score of 100.0%, meaning every household surveyed was living below the context-specific poverty line, lacking access to one or more basic necessities. Few households had a score close to 100.0%, with the overall mean score being 60.3%. This means that a large majority of households lacked access to multiple assets and services deemed locally as basic necessities. Whilst almost all household had access to the most basic items (e.g., those required for cooking), access to services (e.g., schooling and medical) and sanitation (latrines) was only available to a small minority of households. The absence of these key elements represents a serious impediment to development, as meaningful progress is unlikely when so few people have access to adequate education and healthcare. The assessed poverty levels are unsurprising given that 91.0% Madagascar's southern population live below the PPP $1.90 international poverty line (Healy 2018).

Poverty levels were broadly similar between communities, with the exception of Baie d'Italie which had a significantly lower BNS score and is therefore considered to be experiencing higher poverty levels. Comparatively, Baie d'Italie is less accessible by road, further from forest resources, is the only community located south of Fort Dauphin in the study and has had the least historical NGO presence, all of which could influence household poverty. Locally, Sainte Luce is perceived as the wealthiest community. However, poverty levels in Sainte Luce were comparable with the neighbouring fishing communities. This is perhaps surprising given the long history in Sainte Luce of NGO interventions, tourism opportunities and income associated with mining exploration (Kraemer 2012, Seagle 2012). However, there is no counterfactual to determine the level of poverty without the effect of these factors. It may be the case that the opportunities in Sainte Luce have supported the growth of the community (it is the largest of those surveyed) rather than increasing household wealth, or that income generated in Sainte Luce is shared with family members residing outside the community.

CONTRIBUTION OF LOBSTER FISHING TO HOUSEHOLD PROSPERITY. Lobster fishing households had a significantly higher BNS score (i.e., were more prosperous) in all six communities surveyed, demonstrating that lobster fishing plays an important role in in income generation in the region. Whilst there is limited travel infrastructure in this region, it is notable that lobster fishing households are participating in the international spiny lobster supply chain (Long et al. 2021). Although the income fishers receive at the first point of sale is low (~22,000 MGA/kg; 6.80 US$/kg (Long et al. 2021)), relative to the rest of the value-chain, the commodity remains one whose value is attached to lucrative international markets. This is an exception to almost all other potential livelihood activities in the surveyed communities, perhaps with the exception of limited opportunities for NGO or ecotourism related work. The comparatively high value of lobster thus explains the significant positive contribution of the fishery to household income and prosperity.

Fishing households practiced a more diverse range of income-generating activities, i.e., they had a higher mean number of income-generating activities. However, it is not clear whether a greater diversification of income-generating activities drives a higher BNS score, or whether the inclusion of lobster fishing specifically as one of those activities accounts for this difference in poverty levels. The comparatively high income-generating potential of lobster fishing as a livelihood points towards the latter; however, there may be other confounding factors. The broader literature demonstrates that factors determining the extent of rural livelihood diversification are varied, complex, and context-dependent (Ayana et al. 2021, Gebru et al. 2021). For example, in this context declines in catch per unit effort of lobsters may necessitate households employing other livelihood activities in addition to lobster fishing to maintain household income. Additionally, it is important to note lobster fishing households were larger than non-fishing households. It is plausible that larger households are able to engage in more income-generating activities, though a larger household does not necessarily signify the ability to participate in the lobster fishery. In addition, this study specifically assessed only income-generating livelihoods, excluding livelihoods carried out purely for subsistence. It is possible that non-fishing households may rely more highly on subsistence activities. Further studies may wish to investigate which factors drive the pursuit of lobster fishing as a livelihood. Nonetheless, the results highlight the need for effective sustainable management of the fishery and highlight the relative importance of lobster fishing for poverty alleviation and prosperity in southeast Madagascar.

IMPLICATIONS FOR THE MANAGEMENT OF THE LOBSTER FISHERY AND OTHER NATURAL RESOURCES. The income-generating potential of lobster fishing, as demonstrated in this study, explains the increasing effort observed in the regional fishery over the past decades (Long et al. 2021). With few barriers to entry —since all materials can be sourced locally and there are no restrictions on participation—lobster fishing has become critically important for these communities. This significance has implications for fisheries management, particularly in transitioning the fishery to a more sustainable model and enabling stock recovery. Management measures and NGO interventions should be carefully designed to avoid negatively impacting incomes, as this could lead to higher poverty levels. In practical terms, transitioning the fishery toward sustainability would require altering the value chain to ensure fishers can earn more by catching less (Long et al. 2021).

An alternative, or complementary approach is to support the diversification of livelihoods, to reduce the reliance on the lobster fishery and reduce total fishing effort. This is however extremely challenging in this context. Formal employment opportunities are limited, as is access to infrastructure for the movement of goods and people. This creates significant barriers to diversifying livelihoods and increasing income. Accordingly, communities remain isolated in terms of economic opportunities with the exception of their dependence on the lobster fishery and its export controlled by foreign companies (Holloway and Short 2014, Long et al. 2021). Additionally, strong empirical evidence of a link between diversified livelihoods and improved conservation outcomes within small-scale fisheries is sparse, with no guarantee that diversification will result in reduced fishing effort (Roscher et al. 2022). With the high levels of poverty observed in these communities, it is plausible that income derived from initiatives to support diverse livelihoods will be supplementary to fishing income, rather than replacing fishing income.

Collapse or further decline in the productivity of the lobster fishery would have knock-on effects on the status of other natural resources (Brashares et al. 2004). While behaviours such as bush meat harvesting and fishing of endangered sharks would be activities of concern in virtually all marine fisheries with proposed conservation interventions, they are of particularly notable concern within the local context and location. The littoral forest, which many coastal communities rely on for resources, is one of the most threatened ecosystems in Madagascar, having lost up to 90% of its original cover (Ganzhorn et al. 2001, Consiglio et al. 2006, Hyde Roberts 2023). Additionally, exceptionally high rates of flora and fauna across Madagascar are threatened with extinction (Myers et al. 2000, Waeber et al. 2015, Michielsen et al. 2023), including 98% of all lemur species, a third of which are listed as Critically Endangered (IUCN 2020). While the collapse of the fishery would have demonstrated dire socioeconomic implications, onwards pressure on natural resources in the nearby significantly threatened areas would also increase. A limitation of the present study is utilising self-reporting to determine rates of extractive resource use of conservation concern. Some activities of conservation concern such as bush meat harvesting are illegal, and households may have underreported involvement.

BASIC NECESSITIES SURVEY AS A TOOL FOR MEASURING POVERTY. The practical and conceptual challenges of measuring poverty is recognised by both practitioners and academics, arising in part from its multi-dimensional nature and context dependency (see discussion in Flechtner 2021). In this study the BNS approach proved to be a practical, cost-effective solution to measuring poverty levels. It yielded a deeper understanding of levels of deprivation and prosperity, providing a more meaningful, context-specific portrait of poverty and its multidimensional nature, beyond a binary definition of above or below the international poverty line. It also allowed informative comparisons between communities. To monitor conservation and development interventions and their impact on prosperity, it is necessary to measure and track poverty levels within and between communities (Haughton and Khandker 2009). For a resource limited NGO, the BNS proved to be a simple but effective method to collect baseline data related to levels of poverty experienced by households and draw comparisons. Crucially, its relatively quick and inexpensive nature enabled its use within both limited capacity and budget, rendering it an accessible tool. This accessibility is a great strength, especially in response to concerns that the Global North monopolises research into poverty (e.g., Flechtner 2021). Furthermore, the methodology was minimally intrusive and time consuming for participants. It could be argued that the BNS is a means to democratise the measurement of poverty. Its accessibility means it can be widely employed by organisations, or individuals, with limited resource or technical capacity, facilitating research by a greater range of actors in a greater range of contexts.

As discussed in the above sections, measuring poverty using the BNS provided insights relevant to the management of natural resources and assessing conservation actions and their impacts on communities. This functionality has also been reported elsewhere where the BNS has, for example, been successfully used to assess poverty in relation to payment for ecosystem services (Clements and Milner-Gulland 2015); protected areas (Clements et al. 2014) and illegal activities (Wilfred et al. 2019).

The biggest practical challenge faced in conducting the BNS was the lack of direct translation for the phrase "basic necessity" into Malagasy Antanosy (the regional dialect), necessitating further discussion on the best translation for functional equivalence. Whilst the BNS did not require technical expertise, it did require extensive knowledge of the local context, particularly during the design of the basic necessities item list. It is therefore advisable for users of the BNS to work closely with people with expert knowledge of the local context in the design, testing, and delivery of the survey.

A more conceptual limitation arises from the reliance on the core concept of 'basic necessities'. Whilst the BNS by design measures multi-dimensional poverty, perhaps inevitably the phrase 'basic necessities' leads to a focus on tangible assets and services, especially when relying on translation. Broader conceptualisations of poverty include less tangible dimensions such as the opportunity to make choices, participate in social activities and freedom to express oneself. For example, refer to the 'capability approach' developed by Amartya Sen (cf. overview in Robeyns 2005), in which poverty can be viewed as the deprivation of capabilities. It should be recognised that such broader conceptualisations of poverty are not measured by the BNS approach.

The results presented here are consistent with other assessments of poverty (i.e., poverty is prevalent) that have been conducted: in the region, using the US$1.90 PPP international poverty line (cf. Healy 2018); and nationally employing multi-dimensional measures of poverty (e.g., HDI UNDP 2020). This concurrence provides confidence in the validity of the BNS approach, arriving at a similar conclusion but offering particular advantages in terms of depth of understanding and/or the practical merits of the methodology.

CONCLUSION

The BNS proved to be a practical and effective tool for measuring multidimensional poverty, highlighting the widespread poverty in the study area, where all surveyed households were below the context-specific poverty line and lacked access to basic necessities. The survey also highlighted the socio-economic importance of the lobster fishery, showing that households engaged in this activity were experiencing significantly lower levels of poverty. These findings have critical implications for conservation and development in the region, underscoring the need to support the sustainable management of marine resources, which are vital for these communities, while also addressing multidimensional poverty by improving access to basic goods and services. The BNS offers an accessible and powerful method for both practitioners and academics, to measure multidimensional poverty, enabling consistent monitoring and comparison over time and across different locations. We believe the BNS is an underutilised, resource-efficient tool with broad applications in conservation and development.

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SUPPLEMENTARY MATERIAL

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Household survey

Table S1. The 33 potential Basic Necessities Survey items used in household surveys (n=533). The percentage of households who identified each item as a basic necessity is shown for all communities aggregated and items are ordered by frequency of identification. Items shaded in grey were identified by less than 50.0% of participants and were excluded from subsequent analysis.

Figure S1. Diagrammatic overview of Basic Necessities Survey methodology.

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Freshly formed bricks sun-drying in Imerintsiatosika, Itasy Region.
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