VOLUME 4 ISSUE 2 DECEMBER 2009

MADAGASCAR CONSERVATION & DEVELOPMENT

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

IN THIS ISSUE

MWC

Jane Goodall Institut Schweiz

TABLE OF CONTENTS

SPOTLIGHTS

ARTICLES

INTERVIEW

VOICING OVER PICTURES

EDITORIAL

Madagascar – 'down the river without a paddle' or 'turning the corner'?

Throughout the world, Madagascar is positively associated with a diverse range of ecosystems wherein extremely high endemism exists (>80 % of species); however, the nation is also known for high degrees of illiteracy (~30 %), child mortality (~10 % prior to age 5) and increasing poverty levels (>70 % living on < US $ 2 per day). In aggregate, ecological status and socio-economic challenges have attracted widespread international attention. As a result, over the past decade Madagascar has become a primary beneficiary of global support with approximately 25 % of per capita household budget originating from global aide. Continued high levels of international support increase dependency and decrease autonomy.

Since February 2009, destabalizing political turmoil has been responsible for an unprecedented level of natural resource pillaging (e.g., illegal forest harvesting). These environmentally destructive (for many) yet highly profitable (for few) activities involve short-sighted opportunists ready to supply the short-term needs of international markets with a variety of forest-related commodities at the cost of long-term ecological integrity and economic stability. Locals, desperate and struggling to make a living, are coerced to provide the labor base for these endeavors. The impacts stemming from selective and primarily careless extraction of forest resources are widespread and versatile. For example, beyond the removal of trees, rare and endemic fauna are increasingly being used to feed the hard working locals. In addition, numerous species of vascular plants are utilized to float extracted timber (e.g., rosewood) down rivers.

Political regime change in Madagascar has brought with it unstable times able to be taken advantage of by illegal resource extractors. These activities are responsible for a conservation crisis. Surprisingly, little data exist encapsulating the scope of the crisis or what is being done to combat it. The paucity of data and documentation may be due to the high risk associated with rigorous on-the-ground investigations. Some propose that linkages between recent political events and the burgeoning conservation crisis are coincidental, while others think there might be a correlation between the political climate and increased forest resource extraction.

The question arises: Who is to blame? It is far too easy and simplistic to point the finger at the international donor community because it withdrew its support as a consequence of the coup d'état in March. Madagascar would quite possibly fair better if it were less dependent upon external funding. It is probably also far too simple to blame the former or current government due to their inattention associated with ongoing activities in the National Parks and other ecologically important realms. It is difficult to fairly dictate responsibility for the current situation; however, many questions remain relevant: What measures are required for governance of ecologically sensitive and / or valuable areas to decrease vulnerability associated with

political and economic dynamism? How can similar crises be avoided in the future? How can the greater forest system be associated with a higher level of value then the products which it supplies? More imminent questions regard the use forest resources already extracted. What should be done with already extracted wood to effectively halt the logging process and avoid fuelling additional demand?

While the Malagasy media and conservation organizations are absorbed by this ongoing crisis, the future of global climate change actions will be negotiated during the COP15 summit in Copenhagen from 7-15 December (2009). Madagascar will send a delegation to Copenhagen to discuss mechanisms for reducing emissions from deforestation and forest degradation (REDD). Before engaging in REDD there are numerous issues which must be addressed, as is pointed out by the experts interviewed by MCD on REDD. In addition, Barry Ferguson's statement (see REDD article in this issue), "it should be a priority in Madagascar to establish new mechanisms to ensure that individuals and households can directly receive revenues generated by REDD in order to compensate them for losses incurred from lowering deforestation and forest degradation" needs to be emphasized. It is crucial to ensure that communities are directly involved in decisions which impact their short-term and long-term livelihood and well being. Locals are the main players living and depending on the ecosystems that are held in such high regard by the conservation community.

There are countless issues which require our attention and which mandate continued and expanded research to enhance our understanding and inform decision making. In this context, I am very glad to announce this issue's articles represent ongoing work which continues to add to the knowledge and understanding of this complex assemblage of ecosystems. We need to understand why such a crisis emerged to avoid similar events in the future. For the local communities, the forests and their unique ecosystems, cultural and ecological values have no insurance policy allowing a refund in case of damage or loss. Let us hope that Madagascar will have fair and well informed representatives in Copenhagen to ensure that its fate is not 'down the river without a paddle' but more towards 'turning the corner'.

Patrick O. Waeber
Founder Editor

ÉDITORIAL

Madagascar – au fil de l'eau ou en passant le cap ?

Partout dans le monde, Madagascar a une renommée incontestable pour la diversité de ses écosystèmes avec des taux d'endémisme élevés (>80 % des espèces) ; malheureusement, on se réfère aussi à ce pays pour son niveau encore trop élevé d'analphabétisme (~30 %), sa mortalité infantile (~10 % des enfants meurent avant d'avoir atteint l'âge de cinq ans) et un seuil de pauvreté qui englobe de plus en plus de gens (>70 % de gens qui vivent avec moins de US$ 2 par jour) – autant de raisons qui retiennent l'attention des institutions internationales de protection de la nature et de développement. Par voie de conséquence, Madagascar est un des pays les plus dépendants de l'aide extérieure avec un quart de son PIB qui provient de pays étrangers. Ces niveaux permanents d'appui global sont responsables de l'augmentation de la dépendance et de la diminution de l'autonomie.

Depuis le début de la crise politique en février 2009, le degré auquel est opéré le pillage des ressources naturelles (comme l'exploitation forestière illicite) est sans précédent. Ces activités destructrices pour l'environnement (avec de nombreuses victimes) et source d'importants profits (pour une poignée de personnes) sont opérées par des opportunistes aveuglés et prêts à couvrir les demandes à court terme des marchés internationaux en livrant des produits au détriment de l'intégrité écologique et de la stabilité économique à long terme. Des gens du pays, désespérés et luttant pour survivre, sont obligés de travailler à ces tâches. Les impacts de cette exploitation sélective et peu respectueuse des ressources forestières sont répandus et connus. Par exemple, au-delà des arbres, une faune rare et endémique est chassée pour nourrir les bucherons et de nombreuses espèces de plantes vasculaires sont utilisées pour le flottage de ces rondins vers les estuaires des fleuves.

Le changement de régime politique de Madagascar s'est accompagné de périodes instables capables d'attirer des exploitants illégaux de ressources. Ces activités sont responsables d'une crise environnementale. Il y a pourtant peu d'études qui ont porté sur ce type de crise environnementale à Madagascar ou sur ce qui est fait pour y faire face. Le manque d'informations et de données portant sur ces aspects peut vraisemblablement s'expliquer par le risque inhérent à ce type d'investigations sur le terrain. Certains proposent que les liens entre les événements politiques et la crise environnementale ne sont que pures coïncidences mais d'autres pensent voir une corrélation entre le climat politique et l'augmentation de l'exploitation des ressources forestières.

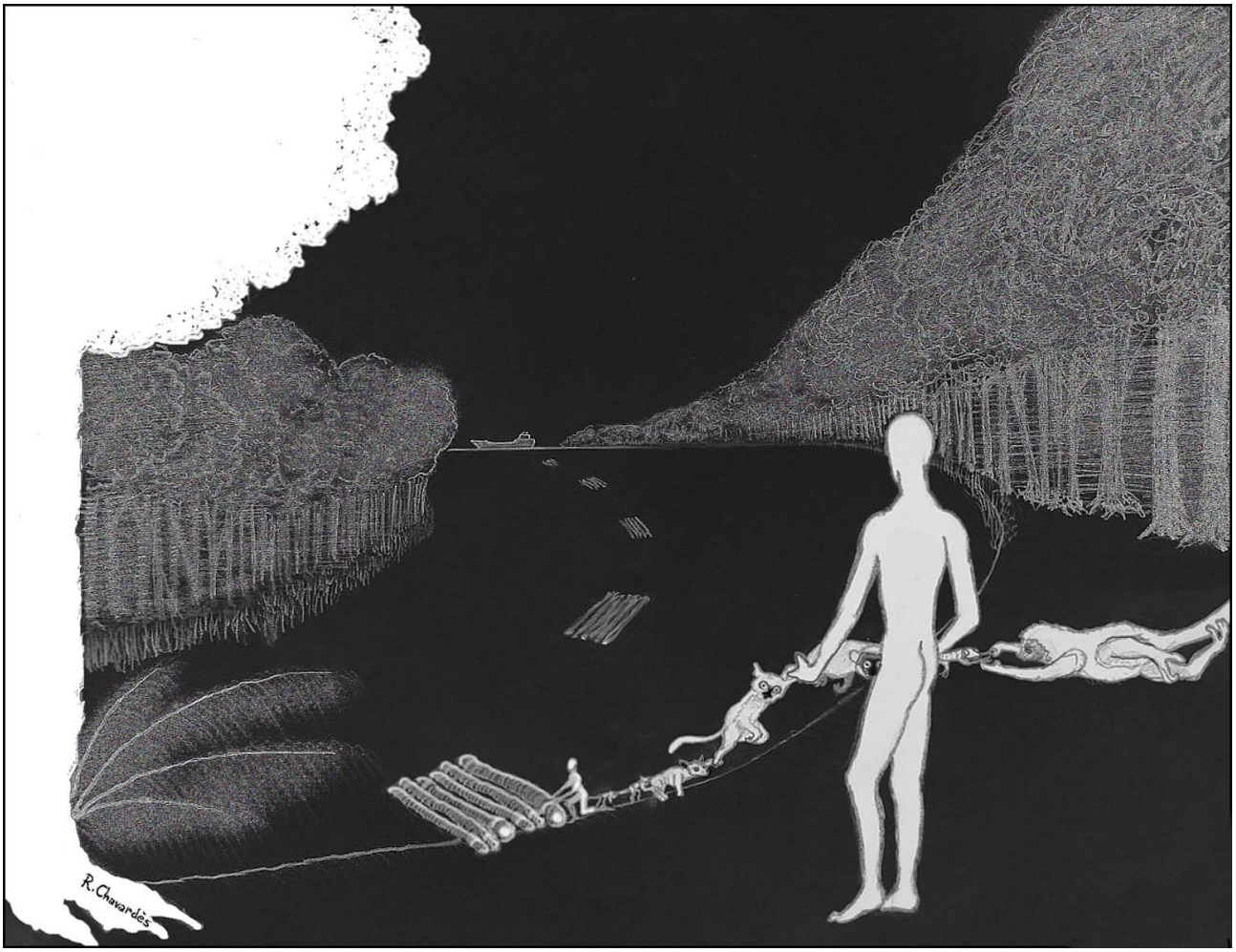
La question qui se pose est : qui peut être blâmé ? Il est certainement trop simple de montrer du doigt les bailleurs internationaux qui ont retiré leur confiance suite au coup d'état de mars. Madagascar se porterait probablement mieux si elle dépendait moins des financements extérieurs. Il en est de même pour le gouvernement précédent ou l'un ou l'autre qui

n'ont pas prêté attention à ce qui se passait dans les parcs et les réserves. Il est difficile d'incriminer cette responsabilité directement. De nombreuses questions restent cependant ouvertes : Quelles mesures doivent être adoptées pour mieux gérer les zones écologiquement sensibles et diminuer leur vulnérabilité face à un dynamisme politique et économique ? Comment de telles crises peuvent-elles être évitées dans l'avenir ? Comment le système forestier dans son ensemble peut-il être associé à un niveau de valeur plus élevé que les produits qu'il abrite? Des questions plus imminentes portent sur l'utilisation des ressources forestières qui sont déjà sorties des forêts. Qu'y a-t-il lieu de faire avec les rondins accumulés pour arrêter l'exploitation illégale et éviter d'entretenir la demande ?

Si les médias et l'attention des acteurs de la protection de la nature de Madagascar sont absorbés par cette crise, l'avenir des actions du changement climatique sera négocié au cours du sommet du COP15 à Copenhague du 7 au 15 novembre. Madagascar enverra une délégation à Copenhague pour défendre les mécanismes de la Réduction des Émissions résultant du Déboisement et de la Dégradation forestière (REDD). Avant de s'engager dans une telle opération, il y a des questions pertinentes qui doivent être abordées et qui sont présentées par des experts en la matière qui ont été interviewés par MCD sur REDD. Je voudrai aussi souligner les propos de Barry Ferguson (voir son article REDD dans ce numéro) qui disent que « la priorité pour Madagascar est d'élaborer de nouveaux mécanismes permettant aux gens et aux ménages de bénéficier directement des revenus produits par REDD afin de compenser les pertes qu'ils consentent en acceptant de réduire le déboisement et la dégradation de la forêt. » Nous devons nous assurer que les communautés de base ne soient plus marginalisées mais qu'elles reçoivent l'intérêt qu'elles méritent, qu'elles soient au centre des actions à mener et des profits à en tirer dans la mesure où elles sont les principales actrices qui vivent et dépendent des écosystèmes qui sont tellement prisés des défenseurs de la nature.

Il y a tellement de thèmes qui méritent qu'on s'y intéresse et pour lesquels des recherches plus approfondies pourraient nous permettre de mieux les comprendre. Je suis donc très heureux de vous présenter les articles qui forment ce numéro et qui rentrent tout à fait dans ce cadre en étant autant d'éléments d'un vaste édifice pour comprendre la complexité du monde. Il nous faudra comprendre un jour pourquoi une telle crise a pu éclater afin de pouvoir les prévenir et les éviter pour le bien être des gens qui vivent dans ces campagnes ainsi que pour les forêts et leurs écosystèmes uniques qui abritent une faune extraordinaire – les uns et les autres n'ont d'ailleurs souscrit à aucune police d'assurances qui pourrait rembourser les pertes en cas de dommage. Souhaitons que Madagascar puisse naviguer au mieux à Copenhague, un peu moins au fil de l'eau mais davantage en passant le cap.

Patrick O. Waeber
Rédacteur Fondateur



FOREWORD

A letter on politics

Before the First World War, politicians of the great powers blustered at each other, believing they defended their national interests. Today they are remembered for provoking the deaths of 15 million people. Before WWII, Germany and Japan each felt they had been deprived of their rightful place in the world. That attitude spawned their expansionist régimes. Seventy million people died. In Copenhagen today politicians from rich and poor nations claim their right to spew the planet's carbon into our atmosphere. There is a difference: the negotiators today in Copenhagen already know that if they fail, they will be responsible not for a few millions but for hundreds of millions of deaths, and misery for billions.

Madagascar is one of many places that people will die from the changing climate. The last decade averaged 2 true cyclones each year, not counting 2-4 more large tropical storms. Science is unclear whether storms and cyclones will become more frequent, but all predictions agree that warming sea temperatures will make them more intense and destructive. And as people of Madagascar's east and west recover from cyclones Fanele, Eric and Jade, drought ravages the south—no one is sure how the rains will change, only that change is coming.

Politicians within Madagascar have little say in the negotiations of Copenhagen, but they have the same problem of balancing short-term advantage over long-term gain. Do they want to spend their time only in political manoeuvers for their parties' gain? If so, they will be remembered for letting people go hungry and allowing the destruction of Madagascar's extraordinary natural heritage. Rosewood export from the national parks and lemur sale as bushmeat are theft from the people of Madagascar, and from the people's future.

Even hungry farmers look to the future. A farmer must be at the last extremity before he or she eats the seed they have saved for next year's planting. Can the politicians of Madagascar and the wider world look beyond this year, beyond this round of elections or negotiations? Do they wish to be remembered as the mothers and fathers who protected their countries' people and the world's heritage of nature, or else like politicians of Europe before the great World Wars, as murderers of the future?

Alison Jolly
University of Sussex

PRÉFACE

Une lettre sur la politique

*Avant la Première Guerre mondiale, les politiciens des grandes puissances se déchaînaient les uns contre les autres en pensant défendre les intérêts de leurs nations. Aujourd'hui on se rappelle d'eux pour leur responsabilité dans la mort de 15 millions de personnes. Avant la Deuxième Guerre mondiale, l'Allemagne et le Japon estimaient avoir été spoliés de la place qui leur revenait dans le monde, attitude qui engendrera leurs régimes expansionnistes. Soixante-dix millions de personnes sont mortes. À Copenhague aujourd'hui, des politiciens de pays riches et de pays pauvres revendiquent leur droit de répandre le carbone planétaire dans l'atmosphère. Mais il y a une différence, car ceux qui négocient aujourd'hui à Copenhague savent que s'ils échouent, ils seront responsables, non pas de quelques millions de morts, mais de centaines de millions de morts et de la misère de m*illiards *d'hommes, de femmes et d'enfants.*

Madagascar est un endroit parmi tant d'autres où les gens mourront du changement climatique. La dernière décennie a été marquée par deux vrais cyclones par an en moyenne, et quelques deux-quatre tempêtes tropicales importantes. Il subsiste bien encore quelques doutes pour prouver scientifiquement dans quelles mesures les tempêtes et les cyclones augmenteront en fréquence mais toutes les prévisions s'accordent au moins pour admettre que l'augmentation de la température des océans les rendra plus intenses et plus destructeurs. Et alors que les gens de l'Est et de l'Ouest de Madagascar se remettent des cyclones Fanele, Éric et Jade, que la sécheresse ravage le Sud, personne ne sait comment les pluies évolueront mais tous s'accordent à reconnaître que changement il y aura.

Les politiciens de Madagascar ont peu de poids dans les négociations de Copenhague, mais sont confrontés au même problème qui consiste à faire la part des avantages à court terme par rapport aux gains à long terme. Veulent-ils se borner à quelques manœuvres politiques pour en faire profiter leurs partis ? Si c'est le cas, on se rappellera d'eux comme ceux qui ont laissé les famines s'installer dans leurs pays et permis la destruction du patrimoine naturel extraordinaire de Madagascar. L'exportation des bois précieux des parcs nationaux et la vente de lémuriens comme gibier sont des vols commis contre les citoyens de Madagascar et contre le futur de l'humanité.

Même les fermiers affamés envisagent l'avenir. Un fermier ou une fermière doit être au bord du désespoir avant de manger les graines qui devraient servir de semences aux plantations de la saison suivante. Les politiciens de Madagascar et du monde peuvent-ils regarder au delà de cette année, au delà de cette série d'élections ou de négociations ? Souhaitent-ils rentrer dans les mémoires comme les mères ou les pères qui ont protégé les citoyens et le patrimoine naturel mondial de leur pays, ou comme les politiciens de l'Europe avant les Grandes Guerres, comme des meurtriers du futur ?

Alison Jolly,
University of Sussex

SPOTLIGHTS

Alternative business models for forest-dependent communities in Africa: A pragmatic consideration of small-scale enterprises and a path forward

Robert A. Kozak

University of British Columbia, Faculty of Forestry
Africa Forests Research Initiative on Conservation and Development (AFRICAD)
2424 Main Mall,Vancouver, BC, V6T 1Z3, Canada
E-mail: rob.kozak@ubc.ca

Plus ça change, plus c'est la même chose.

– Jean-Baptiste Alphonse Karr

ABSTRACT

The dominant mode of business practice in the African forest sector – especially in the high forest cover regions – comes in the form of concessionaires operating on publicly held lands. Increasingly, however, the concession-based model is being challenged. Is it socially and environmentally sustainable? Does it lead to positive socio-economic outcomes for forest-dependent communities? While this paper does not attempt to answer these questions head-on, it does put forward four alternative business models that could serve to reduce poverty and improve social conditions among rural forest-dwelling Africans: 1) small and medium-sized enterprises; 2) community forest enterprises; 3) business associations; and 4) alliances with concessionaires. Definitions of the four business models are provided, and some key considerations for each are discussed. The paper concludes by providing recommendations for civil society, governments, economic actors, communities, and other stakeholders interested in catalyzing and creating an enabling environment for these sorts of business alternatives to succeed in the forested regions of Africa. Namely, there is a need to collect and disseminate quantitative data on the socio-economic contributions that small-scale enterprises can make, devise appropriate interventions that take into account the highly variable socio-political landscapes of Africa, and develop business plans grounded in solid, marketable value propositions.

RÉSUMÉ

Les concessions forestières sur terrains publics constituent le principal mode de gestion du secteur forestier et est plus particulièrement adopté dans les régions disposant d'une couverture forestière importante. Cette pratique est cependant de plus en plus remise en question et certains de se demander se elle est pérenne socialement et pour l'environnement, ou encore si elle permet aux communautés humaines dépendantes de la forêt de profiter de retombées socio-économiques. Si cet article ne prétend pas aborder ces questions directement, il propose cependant quatre modèles économiques qui peuvent être des alternatives aux systèmes basés sur les concessions forestières et qui pourraient permettre de réduire la pauvreté et améliorer les conditions sociales des Africains qui vivent dans les forêts. Ces alternatives proposées pourraient ainsi être de petites et moyennes entreprises (PME), des entreprises forestières communautaires (EFC), des associations professionnelles ou encore des formes d'alliances avec les concessionnaires forestiers. Les PME forestières sont communément rencontrées dans les économies en voie de développement où elles ont vraisemblablement l'avantage de disposer d'un droit acquis auprès des communautés dans lesquelles elles évoluent et constituent un moyen de légitimer les activités économiques informelles ou souterraines. Les EFC sont assez semblables si ce n'est que les forêts et les entreprises locales appartiennent ou sont gérées par les communautés. Elles se répandent de plus en plus dans les économies en voie de développement mais doivent faire face à un certain nombre d'obstacles sur des questions de marché et d'ordre institutionnel. Les associations professionnelles incluent une vaste gamme de regroupements formels et informels de petits producteurs (comme des réseaux ou des circuits) qui peuvent servir pour faire face à des problèmes de petite envergure, une instabilité économique, une absence d'accès à des marchés et un soutien institutionnel limité. Il est important de noter ici que de telles associations peuvent également jouer un rôle primordial pour influencer les discours politiques. Et pour conclure, notons que les concessions forestières ne sont pas prêtes de disparaître dans de nombreuses régions boisées d'Afrique, et ceci étant, les petites entreprises auraient ainsi intérêt à élaborer des alliances stratégiques, des relations contractuelles et des accords de partenariat avec les concessionnaires.

Si chacun des modèles économiques présentés ici à titre d'alternative a ses avantages et ses inconvénients, sans oublier leurs succès et leurs échecs, le but poursuivi dans cet article est de formuler des recommandations destinées à la société civile, aux gouvernements, aux acteurs économiques, aux communautés et à d'autres dépositaires motivés pour catalyser et créer un environnement capable de supporter que de telles entreprises réussissent dans les régions forestières d'Afrique. On note ainsi qu'il y a un réel besoin de récolter et de disséminer les données quantitatives sur les contributions socio-économiques qu'apportent les petites entreprises, mais aussi de concevoir des interventions pertinentes qui prennent en compte la variabilité extrême des paysages socio-politiques en Afrique, et enfin de développer des plans d'action pleinement fondés sur des propositions de valeurs commercialisables.

KEYWORDS: Africa, forests, alternative business models, concessions, poverty alleviation, community wellbeing.
MOTS CLEF : Afrique, forêts, modèles économiques alternatifs, concessions, réduction de la pauvreté, bien-être des communautés.

CONTEXT

Forests play an undeniably important role in the generation of wealth and the creation of employment opportunities for communities around the world. Nowhere is this truer than in the developing world, where it is estimated that forests contribute to the livelihoods and wellbeing of approximately 90% of the world's poorest people (World Bank 2002), either in the form of subsistence uses or income derived from a wide range of timber products, non-timber products, ecosystem services, or conversion to agricultural lands (Arnold 2001, Sunderlin et al. 2005).

At 635 million hectares, forests in Africa comprise about 16% of the world's forests and 25% of the world's tropical rainforests (FAO 2007). Currently, approximately 30% of African forests are dedicated to the production of wood products and non-timber forest products (NTFPs) (ibid), meaning that business concerns have a very tangible bearing on the livelihoods, well-being, sustainability, and social development of the many forest-dependent communities occurring throughout many parts of rural Africa. Paradoxically, amidst this wealth of resources, Africa has the highest percentage of people on the planet living on less than one dollar a day, with 60% of its rural population living below the poverty line (Anderson et al. 2006, Oksanen et al. 2003). Concurrently, forest loss in Africa can reach an annual rate of 1%, exceeding the world average by about four times (FAO 2007), with much of this loss being attributed to forestry-related business activities, both formal and informal.

This leads to some fundamental questions. Perhaps most importantly, what are the most appropriate business models for the production of forest products and services from Africa? This is by no means simple questions to disentangle. To begin with, there are countless business models to choose from and the forest industry is an incredibly diverse sector, encompassing a large basket of forest products and services from medicinal plants to structural lumber products to ecotourism opportunities. In addition, business entrepreneurs and interests can take on many forms, from individuals and families working informally to locally- or collectively-owned small and medium-sized enterprises to large, multinational corporations. In light of this breadth of opportunities and the pressing need to address social, economic and environmental concerns in Africa, perhaps it is more appropriate to be asking what types of business models are best suited to meet both conservation goals related to the sustainability of forests and development goals related to community wellbeing and poverty reduction?

There is a pressing need to take a fresh and long-term look at the future of the forest industry in Africa and to usher in a new era of policies that more effectively contribute to poverty alleviation, local economic prosperity, community wellbeing, and sustainability. This article begins to address some of these fundamental issues by exploring possible business alternatives to the status quo approaches of forestry business in Africa that have dominated since colonization, with a particular focus on smaller-scale forest enterprises.

It then puts forward some considerations (for civil society, governments, economic actors, communities, and other interested stakeholders) which are meant to catalyze dialogue and better inform the debate around appropriate business-related opportunities, programs, interventions, and policy reforms in the forested regions of Africa.

THE STATUS QUO

Since colonization, the dominant mode of business practice in the high forest cover regions of Africa has, by far, been the concession model[1], typically producing lumber products destined for export markets. The history of the concession system is rooted in colonial powers' attempts to develop large, sparsely populated tracts of publicly held land without the use of public funds. However, since decolonization, the practice of gazetted concessions has continued unabated, with concessions currently being granted by governments to large, multinational and mostly foreign-owned (European, but increasingly Asian) companies for set periods of time.

Concessions in Africa are most commonly encountered in countries with high forest cover – Gabon, Congo-Brazzaville, Democratic Republic of Congo, Ghana, Central African Republic, Cameroon, and Equatorial Guinea (Karsenty 2007). Currently, concessionaires in these regions must agree to abide by sets of guidelines (*cahier des charges*) which detail their environmental and social obligations in exchange for their rights to harvest the forest. In recent years, many concessionaires have also been required to craft and follow sustainable forest management plans, and to take on increased social responsibilities, including providing local communities with infrastructure, education, and health services. In some cases, this devolution of public responsibilities into the hands of private interests has led to a 'state within a state' situation wherein the capacity of emerging local governance structures to provide even basic services are undermined (White et al. 2007). National governments and ministries are generally empowered to revoke concessions based on a failure to comply with their environmental and social obligations, but rarely does this happen (ibid). And while there is mounting evidence to suggest that the social and environmental sustainability of concession-based models in Africa is questionable at best (ibid), this is perhaps not even the most salient concern.

In recent years, there has been evidence suggesting that concessions are becoming larger and more consolidated. Yet, concessions – as they currently exist – generally do not provide meaningful development opportunities for local communi-

[1] There are four important caveats which must be stated. First, this analysis considers only the formal concession-based business model which typically produces lumber products for export markets. It does not take into account the large volume of fuelwood that is harvested in Africa, mostly by local peoples, oftentimes informally. Second, this is very much an opinion piece, and while the intent of this paper is to question the efficacy of forest concessions, this business model has led to some positive socio-economic outcomes. The reader is directed to Karsenty (2007) for a more thorough review of how concessions can contribute to employment and economic development in Africa. Third, not all concessionaires are foreign-owned (although the majority are), and the prevalence of concessionaires in Africa varies greatly from country to country, and forest type to forest type. Fourth, concession-based forestry is not solely an African problem. For instance, Canada – the home country of the author – has followed a similar post-colonial trajectory as many African nations, and the dominant mode of business practice in its forests is the concession-based model. As such, Canada faces many of the same problems recounted in this paper and, like Africa, needs to explore options for alternative business models in the forestry sector.

ties, reduce poverty conditions, or contribute to sustainable and equitable growth in Africa. The status quo is simply not working! One needs to look no further than the characteristics and dynamics of concessions currently operating on the continent (with a population of millions) to see that this is true. In Equatorial Guinea, where concessions cover the entirety of the productive forest lands, concessions provide employment to only 2,000 individuals (Karsenty 2007). In Congo-Brazzaville, concessions are designed along arbitrary lines, encompassing 83% of the productive forest lands, as well as villages and agricultural areas; however, only 6,500 individuals are employed nationally (ibid). The share of production allotted to concessions in Cameroon and Ghana – two countries with fairly progressive forestry laws by most standards – are 67% and 63%, respectively, providing employment for a total of approximately 25,000 individuals (ibid). Finally, the Democratic Republic of Congo, currently ushering in new forest policies, which will see the proportion of forest lands dedicated to forest concessions increase from its current level of 25%, provides employment to only 15,000 individuals from its concession forests (ibid).

Notably, the activities of these concessionaires generate significant profits for the companies involved; not a particularly surprising fact given the quality of the resource at hand and the fact that some concessionaires are able to avoid taxation (Greenpeace 2007), or pay prices for timber at well below international parity rates (Birikorang 2007). The forest taxes that are collected translate into sizable revenue streams for national governments. However, there is little in the way of evidence to suggest that the taxes trickle back down to the communities in which the concessionaires are operating. What is known is that many of the forested regions of Africa are rapidly evolving in the global marketplace to become key exporters of commodity wood products like logs and sawn wood, with accumulated export values in excess of one billion dollars annually (Karsenty 2005).

The significance of the concession model on the African forest business landscape is undeniable. However, its efficacy from a poverty reduction point of view can and should be challenged. Specifically, the social and environmental sustainability of this model is questionable, especially in the context of eroding indigenous and customary access and tenure rights of local peoples. But this only leads to further questioning. What then are the most appropriate business models for generating wealth, providing employment, and improving the livelihoods in forest-dependent communities that are subject to social inequity, abject poverty, exclusion, and marginalization?

And amidst this questioning of the status quo, it is important to note one more important bit of context. With a backdrop of vast tracts of forested lands being set aside for use by concessionaires, it is not particularly surprising that a massive informal forestry sector has emerged in Africa. The informal sector (also known as shadow, hidden, illegal, or underground economy) is involved in the harvesting of fuelwood for subsistence, as well as the market-based production of goods and services. In this latter case, incomes from these activities generally go unreported or undetected to authorities, most commonly as a means to avoid registration and evade taxation (Schneider and Enste 2000). One estimate for the size of the informal economy worldwide in forestry puts it at 140 million individuals, most of which occurs in developing countries (Mayers 2006), and in some African countries, the vast majority of business activity falls under the informal economy (Schneider and Enste 2000). Notably, in the case of forest products, the reasons for such activities may go beyond merely lacking the incentive to formally register as a business or tax avoidance. With so much timber being taken up by an entrenched system of concession-based forestry, it is entirely possible that many small-scale producers face scarcities in obtaining timber for production. This leads to one more fundamental question. Given that informal activities are so pervasive in the forestry sectors of Africa, can we come up with business-based solutions that legitimize and legalize these entrepreneurs?

ALTERNATIVE BUSINESS MODELS AND APPROACHES

If we question the status quo approach of concession-based forestry in the high forest cover regions of Africa, then we must do so in a prudent and realistic manner. It is doubtful, and likely counterproductive to believe, that concessions are going to disappear any time soon. This is not to say that change cannot and should not occur, especially in light the global trends towards decentralization of forest ownership and increasing community empowerment. With this comes an imperative to explore and evaluate business models that better serve to support pro-poor forest-based growth and improve the livelihoods of the rural poor in forest-dependent communities. In some instances, this may take the form of something new; an actual business 'alternative'. In other cases, it may be more prudent to catalyze business ventures that complement the ubiquitous concession-based system.

In either case, alternatives to the timber concession model exist, but have yet to gain significant traction in regions of Africa dominated by the concession model. For example, there is sufficient market space, political will, and capacity for a viable economy of smaller-scale, more labor-intensive producers operating in the forest sector to emerge. However, transitioning from a concession-based system to one that is, at the very least, inclusive of small-scale producers is by no means simple. In part, this is due to the current industrial structure undermining the development of new businesses, and specifically, not having the political will to do so (Eifert et al. 2005). More to the point though, the current business climate in Africa for extraction-based industries that are largely export-oriented is hardly conducive to the creation of small-scale businesses (Collier 2000). This speaks to a broader need to examine business issues that constrain business growth, like a lack of access to financing, international markets, transportation, and other business services.

Furthermore, it would be naïve to assume that small business ventures can thrive without a fundamental rethinking of forest governance, regulatory frameworks, and tenure systems. These two constructs – alternative business models and alternative tenure systems – are inextricably linked and need to be considered holistically. After all, what good is creating an enabling environment for small businesses to thrive when they are unable to access local raw materials because the timber has been committed to concessionaires? Interestingly, this is one area where there is a glimmer of hope. Many African nations have recently passed new forest policies or legislation

aimed at reinvigorating the sector and addressing issues of sustainability, with concession reforms, innovative forest tenure arrangements, and log export bans being undertaken in Madagascar, Cameroon, Ghana, and Liberia. While these reforms may not strike at the heart of the problem of poverty alleviation, they do, nonetheless indicate a willingness on the part of governments to explore alternatives which empower and potentially increase the wellbeing of forest-dependent communities.

All that said, four business models stand out as possible alternatives to the status quo approach of concession-based forestry in Africa: 1) small and medium-sized enterprises; 2) community forest enterprises; 3) business associations; and 4) alliances with concessionaires. Each of these smaller-scale business models has been shown to make important contributions to economic development, employment, and community wellbeing in developing regions of the world. However, their success is context-specific and largely dependent on the ability to foster and nurture enabling business environments in the face of the dominant business paradigm of concession-based forestry. In most instances, this depends on the degree to which these small scale enterprises can access timber, build business capacity, and formalize business arrangements between themselves and other supply chain actors. Key issues related to each of these four business models are discussed in turn.

SMALL AND MEDIUM-SIZED ENTERPRISES. In the forest sectors of both developing and developed economies, small and medium-sized enterprises (SMEs) are known to be important sources of employment and locally generated wealth (Kozak 2007). Generally, SMEs are defined as enterprises employing fewer than 250 workers, but in developing countries, the vast majority of cases are far smaller (World Bank 2006). According to Mayers (2006), 80-90% of forest enterprises in many developing countries could be categorized as SMEs, accounting for 50% or more of the forestry-related employment in these regions. In addition, SMEs tend to be vested in the communities in which they operate, and thus have the potential to address issues of forest sustainability and tenure rights directly (Kozak 2007). There is potential for SMEs to focus on a variety of forest-based goods, ranging from value-added wood products, NTFPs, and even commodity products (logs and sawn wood) for domestic markets, and examples of successful SMEs can be seen throughout Africa (in Ghana, Tanzania, and Uganda, for instance). However, the dominance of the export-oriented concession model, and the consequential barriers to the forest resource, can present challenges for the establishment of small production facilities. Furthermore, many SMEs in Africa are subject to overregulation (in the form of cumbersome and costly registration and accounting processes), corruption (in the form of bribery and 'informal' taxation), and limited financing and credit opportunities (ibid). It is little surprise then that many SMEs operating in the forested regions of Africa are relegated to the informal sector, and steps need to be taken to legitimize and enable local enterprise development, and not stifle entrepreneurship.

COMMUNITY FOREST ENTERPRISES. The underlying theory supporting local communities' ownership of forests and enterprises is that vested interests in the local forest resources should lead to positive outcomes with respect to increased biodiversity preservation, sustainable forest management, and profits remaining within the communities (Molnar et al. 2007). However, while community forest enterprises (CFEs) have expanded in recent years in response to the global trend towards decentralized, community control of forest resources, they are also known to have a 'mixed record' in terms of successes and failures (ibid). CFEs can be very profitable, producing a wide range of forest goods and services (ibid). However, they are not without their problems, and there are currently not many examples of truly successful CFEs on the African continent. Most notably, CFEs are subject to many constraints and barriers, such as a lack of business, technical, and management skills, internal social conflicts and political instability, insecure tenure rights, a lack of scale, and market access issues (ibid). Some localities are given community forests in the form of marginal lands that are either not very productive or have recently been logged. For CFEs to prosper in a meaningful, sustainable, and equitable manner, these issues must be tackled head-on through interventions, capacity building, and policy reforms (ibid).

BUSINESS ASSOCIATIONS. Business associations, networks, and clusters represent another strategy for improving the likelihood of success for small forest-based producers. In order to overcome issues of small scale, economic instability, lack of market access, and poor institutional support, these aggregations of small like producers – either formal or informal – exist for an "articulated common purpose" and with the aim of achieving "collective efficiencies" (Macqueen 2004). These can come in the form of cost-sharing, information exchange, the development of long-term business relationships and contractual obligations along the supply chain, decreased production and distribution costs, greater access to credit, lower risks, and increased access to global markets, to name a few examples (Biggs and Shaw 2006, Macqueen et al. 2006). Perhaps more importantly, these associations can also play an important role in policy reform and poverty alleviation by acting as advocates for rights and improved conditions. One emergent possibility comes in the form of web-based technologies which can serve the dual purposes of aggregating small wood producers (e.g., makers of arts and crafts goods) and distributing these goods to international markets. However, one need also be cognizant of the fact that many forest-dependent communities do not have electricity, let alone internet access.

ALLIANCES WITH CONCESSIONAIRES. One possibility to catalyze business opportunities in regions of Africa where concessions are prevalent would be to explore and facilitate strategic alliances between concessionaires and small, community-based forest businesses. Done properly through contractual arrangements and formal partnering agreements, these sorts of alliances may serve to firmly embed small producers into international supply chains that would otherwise be out of reach. The roles of small businesses may vary from situation to situation, but it is not far-fetched to imagine community-based businesses as suppliers of high value timber to concessions, or smaller producers of value-added wood products using raw materials processed locally in concession sawmills. Interestingly, local wood markets are often brimming with higher-value products made of wood species that concessionaires prefer not to use. One possible solution, then, would be for concessions and small millwork and furniture manufacturers to form alliances to enable the latter party to access these under-utilized species (including bamboo and rattan) from gazetted concessions.

THE PATH FORWARD

The existence of a vibrant sector of small-scale forest enterprises – as alternatives to the status quo approach of concession-based forestry – can provide a firm foundation for economic development and poverty reduction in many of the forested regions of Africa. Alternative business models and approaches, such as small and medium-sized enterprises, community forest enterprises, business associations, and alliances with concessionaires, could provide significant employment opportunities to the rural poor. In addition, small-scale enterprises can generate benefits that go beyond economic development to address broader sustainability issues like community building, social equity, empowerment and security, and forest conservation (Macqueen et al. 2006). And yet, it has been difficult for such business ventures to gain any meaningful traction in the forests of Africa. While it is easy to point the finger at the many systemic and endemic problems that seem to pervade the political economies of Africa, oftentimes, this lack of momentum can be attributed to well-intended, but ill-conceived, interventions. Researchers, civil society, governments, and other interested stakeholders are advised to consider the following issues prior to engaging in programs dedicated to catalyzing small-scale forestry businesses in Africa.

The first order of business in putting forward business alternatives for the forestry sectors of Africa would be to address the veritable paucity of data that exists surrounding the socio-economic contributions that smaller-scale forestry enterprises can and do make. This is very much in line with the call by Angelsen and Wunder (2003) to quantify and provide further clarity on the roles of smaller-scale forestry enterprises in pro-poor growth for developing regions, through literature reviews, secondary data analyses, and primary data collection and analyses (case studies, enumerated surveys, etc.). Some data regarding wealth and employment creation has been collected, but it is sparse and oftentimes dated. And while the literature on smaller-scale business alternatives in Africa decisively speaks to the potential economic contributions that such enterprises can make to employment creation, community well-being, and poverty reduction, it also tends to be rife with fairly vague and sweeping statements. If we wish to move the debate on business alternatives forward among policy makers and key decision makers, we must go beyond anecdotal evidence and kneejerk assumptions by providing them with empirically substantiated findings related to economic development. Only then, can we make informed and strategic decisions regarding the efficacy and appropriateness of policies and interventions related to the promotion of business alternatives.

This leads to a second issue, namely what types of interventions are most appropriate for catalyzing small-scale businesses in the African forestry sector? This is a complicated question – perhaps the subject of another paper – but it is worth noting a few points. Providing support for smaller-scale enterprises in developing countries has generally been viewed by civil society and governments as an appropriate means of reducing poverty and spurring economic growth; the World Bank has poured billions of dollars into such programs in the past decade (Beck and Demirguç-Kunt 2004, Beck et al. 2004). One of the most appealing attributes of enterprises like SMEs and CFEs is that they are very labor-intensive and are, thus, a good source for newly created jobs. However, others have argued that larger firms (like concessionaires) are better suited to providing high quality jobs over the long-term due to their economies of scale, market reach, and higher likelihood for success (ibid).

The reality is that the truth likely lies somewhere in the middle, and perhaps the more salient question should revolve around the precise forms that interventions should take. Direct financing of small enterprises (including providing seed money for startups and microcredit / financing) is seen as a viable and affective means of catalyzing growth in developing regions (Biggs 2002). However, many authors caution against the provision of subsidies (Beck and Demirguç-Kunt 2004), while others speak to the urgent need to include programs that build capacity in the form of business training and assistance (Donovan et al. 2006). Interestingly, some factions of civil society are currently in the midst of questioning the long-term efficacy of direct financing programs and are increasingly redefining their roles to lead debate on policy reform and provide longer-term, market-based solutions that serve to create enabling environments for smaller-scale enterprises to legally exist, compete fairly and, ultimately, prosper (Scherr et al. 2003). It goes without saying that this sort of discourse must begin with fundamental policy questions regarding forest tenures and the rights of communities to access forest lands.

Last but certainly not least, programs designed to support small-scale forest-based businesses in Africa must adhere to sound business principles in order to be effective and successful. For each business venture, this begins with a thorough grasp of the value proposition at hand and a realistic understanding of the respective market opportunities. For example, it is simply not prudent to expect a small forest enterprise to be able to compete against concessions by selling low-value commodity wood products (e. g., logs and sawn wood) into global markets. However, it is realistic to assume that they can sell higher value wood products (e.g., furniture and millwork) into smaller, local niche markets, which are becoming increasingly important within the African continent (Kozak and Canby 2007). Nor is it advisable to subscribe to a silver bullet notion of a single product or market that will lift rural forest-dwelling Africans out of poverty. In reality, the most successful small-scale forest enterprises will likely be the ones that have multiple revenue streams achieved through diversified product and service offerings, including timber goods, NTFPs (e.g., edible and medicinal plants), and ecological services (e.g., carbon sequestration). This sort of strategy not only increases the profit potential of a business proposition, but reduces business risk by providing a buffer for seasonal production, market downturns, and other economic shocks (Kozak and Canby 2007).

All that said, it would be foolhardy to approach a new business proposition without a thorough and thoughtful consideration of the socio-political context within which business enterprises are situated. This will vary from country to country, forest type to forest type, and even region to region, with each having its own unique set of institutions, business and investment climates, infrastructures, forest tenure policies, and natural ecosystems (Kozak and Canby 2007). A solid grounding of the broader political economy at play is essential to formulating what types of businesses, and business interventions, are most appropriate in each of the forested nations of Africa.

Prior to traipsing down the road of programs, interventions, and policy reforms designed to stimulate and create an enabling

environment for small-scale forestry businesses in Africa, there is a pressing need for resolution (and data!) on these and other issues. Without such information on hand, how can we possibly know what types of business opportunities work best for the widely differing contexts and situations that occur in the forests of Africa? How can we be sure that our interventions will have positive and measurable impacts on community development and poverty reduction? Worse still, despite our good intentions, do we run the risk of not affecting change at all, and perhaps even perpetuating the status quo of social exclusion and poverty in Africa?

REFERENCES

Anderson, J., Benjamin, C., Campbell, B. and Tiveau, D. 2006. Forests, poverty and equity in Africa: New perspectives on policy and practice. International Forestry Review 8, 2: 44-53. (doi:10.1505/ifor.8.1.44)

Angelsen, A. and Wunder, S. 2003. Exploring the Forest–Poverty Link: Key Concepts, Issues and Research Implications. Center for International Forestry Research (CIFOR), Occasional Paper No. 40. Bogor, Indonesia.

Arnold, J. E. M. 2001. Forestry, Poverty and Aid. Center for International Forestry Research (CIFOR), Occasional Paper No. 33. Bogor, Indonesia.

Beck, T. and Demirguç-Kunt, A. 2004. SMEs, Growth, and Poverty: Do Pro-SME Policies Work? The World Bank Group, Private Sector Development Vice Presidency Note Number 268 (February 2004). Washington, D. C.

Beck, T., Demirguç-Kunt, A. and Levine, R. 2004. SMEs, growth, and poverty: Cross country evidence. Journal of Economic Growth 10, 3: 199-229. (doi:10.1007/s10887-005-3533-5)

Biggs, T. 2002. Is Small Beautiful and Worthy of Subsidy? Literature Review. International Finance Corporation (IFC). Washington, D. C.

Biggs, T. and Shah, M. K. 2006. African Small and Medium Enterprises, Networks, and Manufacturing Performance. World Bank, Policy Research Working Paper 3855. Washington, D. C.

Birikorang, G. 2007. Summary Overview Report of the Status of Forest Industry and Trade in Central and West Africa. Rights and Resources Initiative, Washington, D. C.

Collier, P. 2000. Africa's comparative advantage. In: Industrial Development and Policy in Africa. H. Jalilian, M. Tribe and J. Weiss (eds.), pp 11-21. Edward Elgar Publishing, Cheltenham, U. K.

Donovan, J., Stoian, D., Macqueen, D. and Grouwels, S. 2006. The Business Side of Sustainable Forest Management: Small and Medium Forest Enterprise Development for Poverty Reduction. Overseas Development Institute (ODI), Natural Resources Perspective 104. London, U. K.

Eifert, B., Gelb, A. and Ramachandran, V. 2005. Business Environment and Comparative Advantage in Africa: Evidence from the Investment Climate Data. Working Paper Number 56. The World Bank. Washington, D. C.

FAO. 2007. State of the World's Forests, 2007. Food and Agricultural Organization of the United Nations. Rome, Italy.

Greenpeace. 2007. Carving up the Congo. Greenpeace. Amsterdam, Netherlands.

Karsenty, A. 2005. Wood in Central Africa: A problem of governance. African Geopolitics 17: 97-110.

Karsenty, A. 2007. Overview of Industrial Concessions and Concession-Based Industry in Central and West Africa, and Considerations of Alternatives. Rights and Resources Initiative, Washington, D. C.

Kozak, R. 2007. Small and Medium Forest Enterprises: Instruments of Change in the Developing World. Rights and Resources Initiative / University of British Columbia, Washington, D. C.

Kozak, R. and Canby, K. 2007. Alternative Tenure and Business Models for Pro-Poor Growth in Central and West Africa: New Analytical Work on Alternative Business Models. Rights and Resources Initiative (RRI), Concept Note. Washington, D. C.

Macqueen, D. 2004. Associations of Small and Medium Forest Enterprise: An Initial Review of Issues for Local Livelihoods and Sustainability. International Institute for Environment and Development (IIED), Briefing Paper. London, U. K.

Macqueen, D., Bose, S., Bukula, S., Kazoora, C., Ousman, S., Porro, N. and Weyerhaeuser, H. 2006. Working Together: Forest-Linked Small and Medium Enterprise Associations and Collective Action. International Institute for Environment and Development (IIED), Gatekeeper Series 125. London, U. K.

Mayers, J. 2006. Small- and medium-sized forestry enterprises. International Tropical Timber Organization (ITTO) Tropical Forest Update 16, 2: 10-11.

Molnar, A., Liddle, M., Bracer, C., Khare, A. , White, A. and Bull, J. 2007. Community-Based Forest Enterprises: Status and Potential. ITTO Technical Series #28. International Tropical Timber Organization / Forest Trends / Rights and Resources Initiative, Washington, D.C.

Oksanen, T., Pajari, B. and Tuomasjukka, T. 2003. Executive Summary. In: Forests in Poverty Reduction Strategies: Capturing the Potential. T. Oksanen, , B. Pajari and T. Tuomasjukka (eds.). EFI Proceedings No 47. European Forest Institute, Joensuu, Finland. <http://www.efi.int/portal/virtual_library/publications/proceedings/47> accessed 15 January 2009.

Scherr, S. J., White, A. and Kaimowitz, D. 2003. A New Agenda for Forest Conservation and Poverty Reduction: Making Markets Work for Low-Income Producers. Forest Trends / Center for International Forestry Research (CIFOR). Washington, D. C. / Bogor, Indonesia.

Schneider, F. and Enste, D. H. 2000. Shadow economies: Size, causes, and consequences. Journal of Economic Literature 38, 1: 77-114.

Sunderlin, W. D., Angelsen, A., Belcher, B., Burgers, P., Nasi, R. Santoso, L. and Wunder, S. 2005. Livelihoods, forests, and conservation in developing countries: An overview. World Development 33, 9: 1383-1402. (doi:10.1016/j.worlddev.2004.10.004)

White, A., Rhein, M., Kozak, R., Karsenty, A., Birikorang, G., Samjee, A.-S. and Bull. J. 2007. Forestry and Pro-Poor Growth in Central and West Africa: Opportunities for Alternative Tenure and Business Models. Rights and Resources Initiative (RRI), Concept Note. Washington, D. C.

The danger of misunderstanding 'culture'

Eva Keller

Department of Social Anthropology
University of Zurich
Andreasstrasse 15, 8050 Zurich, Switzerland
Phone: +41 52 222 95 35
E-mail: e.s.keller@bluewin.ch

ABSTRACT

Most conservationists working in Madagascar recognise that if conservation goals are to be achieved, conservation bodies have to work together with, rather than against, local people. One important aspect of this is taking local 'culture' into account. However, what is understood by 'culture' in such contexts tends to be extremely partial as 'culture' is almost always limited to taboos (*fady*). The article discusses the danger of such a narrow view suggesting that 'culture' is infinitely more complex and subtle than its immediately apparent surface. I argue that if conservationists' commitment to take 'culture' seriously is genuine, it must also apply to those cultural phenomena that are in conflict with conservation programmes. This applies in particular to rural Malagasy people's desire to have many descendants; a desire which is linked to their fundamental understanding of what represents a meaningful life.

RÉSUMÉ

La plupart de ceux qui travaillent dans des institutions dédiées à la protection de la nature se rendent bien compte que s'ils veulent réussir dans leur entreprise ils doivent travailler avec, et non contre, la population locale. Pour cela il est important de tenir compte de la 'culture'. Néanmoins, ce qu'ils englobent dans le terme 'culture' est fort limité et le plus souvent réduit aux seuls tabous (*fady*). L'article considère les dangers qu'une telle limitation implique et démontre que la culture est quelque chose d'infiniment plus complexe et subtile que ce qui apparaît en surface. Je ne doute pas de la bonne foi des protecteurs de la nature qui veulent tenir compte de la culture mais je tiens ici à souligner qu'ils doivent aussi accepter l'existence d'aspects culturels qui vont à l'encontre de leur programme, car déclarer vouloir travailler avec les habitants ne serait qu'une parade s'il en était autrement. Mon analyse porte sur l'ensemble des aspects liés au désir d'avoir une progéniture nombreuse pour les populations rurales malgaches. Être humain consiste avant tout à avoir de bonnes relations et définir une morale entre les membres de générations différentes d'une famille, dans le passé, le présent et le futur, car c'est cela que d'avoir une famille. Ces relations sont créées et maintenues de diverses manières au quotidien et dans la vie rituelle mais plus particulièrement au niveau des enfants car ils représentent la bénédiction ancestrale et comme ils relient les vivants et les morts, ils créent le lien entre le passé, le présent et l'avenir du groupe de parenté. Ainsi si les protecteurs de la nature veulent être crédibles dans leur désir de prendre en compte la 'culture' malgache, ils ne peuvent pas limiter leur approche à la reconnaissance de tabous sans reconnaître d'autres aspects de la culture malgache comme le désir d'avoir une progéniture nombreuse qui ne s'accorde généralement pas avec le programme actuelle de protection de la nature.

KEYWORDS: Culture, taboo, Masoala, population growth, concepts of life, Madagascar.
MOTS CLEF : culture, tabou, Masoala, croissance demographique, conceptualisation de la vie, Madagascar.

THERE IS MORE TO 'CULTURE' THAN TABOOS

Conservationists working in Madagascar seem to have come to an agreement that if conservation is to succeed, conservation bodies have to work together with local people. One important aspect of this is taking local 'culture' into account. Few are those who would nowadays argue against this paradigm. To a social scientist such as myself, however, the conservationists' use of 'culture' is highly problematic because it reveals a partial and misleading understanding of what it means to acknowledge and to integrate 'culture'.

In the conservation literature that addresses the problem of biodiversity conservation in Madagascar, taking 'culture' into account is regularly equated with integrating local taboos (*fady*) into conservation programmes, although, of course, this applies more strongly to some studies than to others. The tendency to reduce 'culture' to *fady* includes numerous references to so-called 'sacred forests' where in many cases taboos against cutting vegetation or killing animals apply. I would like to add here in brackets that 'sacred forest' is a problematic and misleading translation of *ala fady* for two reasons. First, it is taboo to cut the vegetation in such a place not because of the vegetation but because it is taboo to disturb the ancestors that rest inside the *ala fady*. Second, one should be wary of thinking of Malagasy ancestors in terms of 'sacredness' in the European sense. Rather than being 'supernatural' beings or subjects of religious veneration, people in Madagascar think of ancestors in ways that are strogly connected to how they think of elders (Bloch 2002).

Although 'culture' is never explicitly reduced to taboos, whenever an argument is made for integrating 'local culture' for the sake of conservation it almost always and almost exclu-

sively concerns taboos. This was evident, for example, during a conference on 'Society, Natural Resources and Development in Madagascar' held at the University of East Anglia in the spring of 2007 during which a number of speakers emphasised in one breath how it was imperative for conservationists to be sensitive to 'local culture' and to learn about and take into account *fady* in order to win villagers over to conservation objectives (see also Mannle et al. 2008). The near equation of 'integrating culture' with 'integrating taboos' is also evident, for instance, in several contributions made to this journal. In these, authors make references to 'tradition' and 'culture' by, on the one hand, pointing to the value of taboos for conservation (Rabearivony et al. 2008, Rahaingodrahety et al. 2008) and, on the other hand, by lamenting the (increasing) lack of respect for local *fady* by migrants or local people themselves and the detrimental effect that this has on the environment (Patel 2007, Rasolofoson et al. 2007). Hardly any mention of 'culture' is otherwise made in the conservation literature.

When I talk of 'conservation literature', I refer to studies on biodiversity conservation in Madagascar by non-social scientists who discuss a phenomenon, 'culture', that is typically the realm of the social sciences. This breach of disciplinary boundaries is of course highly desirable and I do not in any way want to suggest that non-social scientists would do better to leave 'culture' out. However, a deeper understanding of what 'culture' is is necessary if 'culture' is not to be used merely as a means to an end. Thus I would like to have this essay understood as a social scientific contribution to an interdisciplinary discussion.

Conservationists' interest in taboos is understandable. By definition, taboos give information about things one must not do. As conservation programmes in Madagascar are primarily aimed at preventing Malagasy people from doing certain things, such as eating lemurs or bats or felling trees, taboos seem to provide a perfect, culturally anchored tool for getting the message across. This is undoubtedly true in certain contexts. However, the compatibility between certain taboos and conservation objectives in Madagascar creates an unfortunate tendency among conservationists to prioritize taboos over other aspects of life in Madagascar that are equally part of 'culture'.

The almost exclusive focus on *fady* produces a limited picture of what a commitment to taking 'culture' seriously implies. Obviously, taboos are an important aspect of Malagasy society but they are only one element, and a relatively minor one, of the complex totality that is normally referred to as 'culture'. *Fady* can easily be found out about and noticed even by a casual observer, but they mean little when isolated from the wider cultural context of which they form a part. I will not attempt a definition of 'culture' here not only because this would be an inappropriate place to do so but also because the very complexity of what is referred to by the word 'culture' has meant that defining it has been notoriously difficult. One thing, however, that social scientists agree on is that much, if not most, of 'culture' is not explicit (cf. Geertz 1973). Thus 'culture' cannot be reduced to those of its aspects that can easily be elicited from local people such as what kinds of *fady* exist in a particular place. 'Culture' is infinitely more complex and subtle as the work of several generations of anthropologists amply demonstrates. Thus conservationists' commitment to respect local 'culture' and to work with, rather than against, it should be understood in a much broader sense than is usually the case. Moreover, if this commitment is to be genuine, it must also apply to those aspects of Malagasy 'culture', which are in conflict with conservationist programmes. Otherwise the commitment to work with local people is merely self-serving. Consider the following brief illustration of what taking 'culture' into account will inevitably imply (for a much more detailed account and discussion of the argument summarised below, see Keller 2008). The following account is based on a total of twenty-nine months of social anthropological fieldwork carried out on the Masoala peninsula and in the area of Maroantsetra (see Keller 2005, 2008, 2009).

WHAT CONSTITUTES A MEANINGFUL LIFE?

At the end of a long conversation that my research assistant Paul and I had with an old woman and two of her sons during the course of my recent fieldwork on the Masoala peninsula, we came to talk about the joy the Malagasy feel when they have produced many descendants. Rounding off the conversation, Paul recounted the following myth: "The Creator asked the Malagasy whether they preferred to die the way a banana plant dies or the way the moon dies. The Malagasy chose the banana plant because after it dies many new banana plants will still grow from its base. But when the moon dies it leaves no children behind." The myth was met with pleasure by those listening because of how well it captured what everyone felt. The banana tree, although it only lives for a short period of time, produces many new shoots that grow right out of their parent plant, sprouting around it while it is still alive and continuing to grow even after it has died. The moon, in contrast, although it is eternal and never truly dies, does not grow and does not produce new life. "The moon of February is still exactly the same in March, in April and in May; it's still just one single moon," Paul added. "The moon has no children. Or", looking with a smile on his face at his audience, he ended, "has anyone ever heard of a child of the moon, or of its brother?" "No, there isn't any such thing," said the old lady laughing.

As my own work and that of other anthropologists shows (e.g. Southall 1986, Feeley-Harnik 1991: 51-56, Bloch 1993, Astuti 2000), the desire to have many descendants is almost universal in rural Madagascar. The reasons for this are subtle and complex and population growth cannot be reduced to a strategy aimed at economic or social security in old age as is often assumed, much less can it be explained by local people's lack of formal education. Rather, rural Malagasy people's wish to have numerous descendants is intimately linked to their understanding of what, at a very fundamental level, represents a successful and meaningful life.

It is important to note that the concept of descendants in Madagascar (*taranaka*) includes not only one's own children, grandchildren, great-grandchildren and so on but also the children, grandchildren etc. of all of one's brothers, sisters and cousins. All these people, together with all those who have generated them and those who will come after them, constitute a kin group. A kin group thus includes ancestors, their presently living and their future descendants. And it is the relations between these different generations of relatives that, in rural Madagascar, primarily constitute a person's identity and place in society. Thus kinship (*fihavanana*) – a notion that, however, involves much more than genealogy referring, in particular, to moral ties and obligations – is at the core of what

it means to be a human being. Therefore, the purpose of life, as people in Masoala, for example, understand it, is to continue and to strengthen the relations between the different generations of people who together constitute a kin group. These relations are maintained and created in many ways in daily and in ritual life but in particular through the generation of children. The birth of a healthy child is a sign that the ancestors are satisfied and that they have therefore blessed their descendants with a new life; when ancestors are angry they may deprive their descendants of children. Children also ensure that the good relations between living and dead relatives will continue in the future. Because on the one hand, they will communicate with, and care for, their ancestors – those who were already dead when they were born and those who will become ancestors during their lifetime. This happens, for example, by sacrificing cattle for the ancestors or by asking for their blessing before undertaking particular types of agricultural work or when setting off on a journey. On the other hand, children will generate new children who will further continue the moral relationships between past, present and future generations. Children thus link the present to the past and to the future. The success of the relationships among kin does not necessarily depend on every couple having lots of children and it is indeed not the case that all families have or even want many. In the three villages in the district of Maroantsetra where I have worked since 1998, many women and men had only two or three children while others had eight or more and some none. People's desire to have many descendants – and, as we have seen, these include far more people than one's own children and grandchildren – is not measurable or quantifiable and it does not follow a simple logic of 'the more, the better' (cf. Feeley-Harnik 1995). However, from the perspective of an ethos that is oriented towards the fruitful continuation of the relations between relatives of different generations, dead and alive, every new human life is a positive event that strengthens these ties and therefore growth is good. It is because, for people in a place like Masoala, a successful life is one that makes kin groups prosper and preferably grow that the Malagasy chose the fate of the banana plant and not the moon's static eternity. In a rural society, however, a kin group's successful growth not only depends on the birth of children but also, equally importantly, on a family's ability to provide them with land on which they can create a livelihood and continue the productive process of life. This land is referred to in Masoala, as in other parts of Madagascar, as *tany fivelomana* – from the root *velona* (to be alive) – which means not only 'land for subsistence' but also 'land for life' in the sense of enabling the process of continuation and growth discussed above (Abinal and Malzac 1993: 824).

None of this, of course, means or implies that 'culture' is fixed or static, on the contrary. As is true of all human societies, Malagasy 'culture' is dynamic, processual and thus in constant flux. Nonetheless, there are, at a given time, outstandingly important cultural markers such as rural Malagasy people's conceptualisation of a meaningful and moral life as being based on the good relations between dead and living kin.

In the case of the Masoala peninsula, the Masoala National Park that was established in 1997 already severely restricts local people's access to land now and, unless things change dramatically, will do so even more in the future when the next generations will not be permitted to turn forest or secondary growth into *tany fivelomana*. In the villages where I work, the park is therefore perceived by local farmers as a threat to the successful continuation of the good relations between relatives of past, present and future generations. This makes people feel, as many have said to me, 'defeated' (*resy zahay*) in the very purpose of life. From this perspective it is rather ironic that ANGAP, now called Madagascar National Parks, should have chosen as its new slogan the phrase 'For Life'.

The 'ethos of growth', including ideas about children, land, rice, kinship, ancestral blessing, progress, prosperity and a great many other things, is never explicated by local people in a way comparable to what I have just done. Rather it is embedded and implicit in countless actions and practices, remarks, reflections, bodily gestures and emotions that occur in the course of daily life. The 'ethos of growth' is a crucial aspect of contemporary 'culture' to be found beneath that which is explicit, visible and easily discovered, such as what kinds of *fady* people have in a particular place.

IMPLICATIONS

If conservationists' commitment to work with, rather than against, local people and to take their 'culture' into account is sincere, then 'culture' must be acknowledged not only when it happens to suit conservation objectives as in the case of taboos against eating certain kinds of lemurs or cutting trees in particular places. Rather, 'culture' must be recognised in a much more encompassing sense, including people's desire to have many children and their need for land. What exactly this will imply in the context of conservation activities is another issue that is not the topic of this essay which, rather than proposing any particular solutions to the problems discussed, is intended to provide food for thought. If only things such as *fady* and 'sacred forests' are promoted as valuable 'culture' in the conservation literature, this may give rise to the suspicion that what we are really dealing with is an unsettling attempt to use 'culture' simply in order to better sell to the Malagasy what they might, in fact, not want.

ACKNOWLEDGEMENTS

This article is based on research in Masoala generously funded by the Swiss National Science Foundation (2006–2009). I express my thanks to Maurice Bloch and Jacques Pollini for their suggestions in response to an earlier draft of this essay. I also thank the three anonymous reviewers for MCD for their comments. Although it is unlikely that many of my friends in Masoala will ever read this text, I express my gratitude to them all for sharing with me what troubles them. I have written this text in the hope that it might contribute towards making their voice heard.

REFERENCES

Abinal, A. & Malzac, V. 1888 [reprinted 1993]. Dictionnaire Malgache–Français. Ambozontany, Fianarantsoa.

Astuti, R. 2000. Kindreds and descent groups: New perspectives from Madagascar. In: Cultures of Relatedness: New Approaches to the Study of Kinship. J. Carsten (ed.), pp 90-103. Cambridge University Press, Cambridge.

Bloch, M. 1993. Zafimaniry birth and kinship theory. Social Anthropology 1 (1B): 119-132. (doi:10.1111/j.1469-8676.1993.tb00245.x)

Bloch, M. 2002. Are religious beliefs counter-intuitive? In: Radical Interpretation of Religion. N. K. Frankenberry (ed.), pp 129-146. Cambridge University Press, Cambridge,

Feeley-Harnik, G. 1991. A Green Estate: Restoring Independence in Madagascar. Smithsonian Institution Press, Washington, D. C.

Feeley-Harnik, G. 1995. Plants and people, children or wealth? Shifting grounds of 'choice' in Madagascar. Political and Legal Anthropology Review 18, 2: 45-64. (doi:10.1525/pol.1995.18.2.45)

Geertz, C. 1973. Thick description: Toward an interpretive theory of culture. In: The Interpretation of Cultures. Selected Essays. C. Geertz (ed.), pp 3-30. Basic Books, New York.

Keller, E. 2005. The Road to Clarity. Seventh-day Adventism in Madagascar. Palgrave Macmillan, New York and Houndmills.

Keller, E. 2008. The banana plant and the moon: Conservation and the Malagasy ethos of life in Masoala, Madagascar. American Ethnologist 35, 4: 650-664. (doi:10.1111/j.1548-1425.2008.00103.x)

Keller, E. 2009: Who are "they"? Local understandings of NGO and state power in Masoala, Madagascar. Tsantsa 14: 76-83.

Mannle, K., Tora, E. and Radaniarison, H. T. 2008. Specific-species taboos and biodiversity conservation in Northern Madagascar. Paper presented at the annual meeting of the International Congress for Conservation Biology, Chattanooga, TN, July 10, 2008. Abstract available at <http://www.allacademic.com/meta/p_mla_apa_research_citation/2/4/4/2/2/p244226_index.html>

Patel, E. R. 2007. Logging of Rare Rosewood and Palisandre (*Dalbergia* spp.) within Marojejy National Park, Madagascar. Madagascar Conservation & Development 2, 1: 11-16.

Rabearivony, J., Fanameha, E., Mampiandra , J. and Thorstrom, R. 2008. Taboos and social contracts: Tools for ecosystem management – lessons from the Manambolomaty Lakes RAMSAR site, western Madagascar. Madagascar Conservation & Development 3, 1: 7-16.

Rahaingodrahety, V. N., Andriafidison, D., Ratsimbazafy, J. H., Racey, P. A. and Jenkins, R. K. B. 2008. Three flying fox (Pteropodidae: *Pteropus rufus*) roosts, three conservation challenges in south-eastern Madagascar. Madagascar Conservation & Development 3, 1: 17–21.

Rasolofoson, D., Rakotondratsimba, G., Rakotonirainy, O., Rakotozafy, L. M. A., Ratsimbazafy, J. H., Rabetafika, L., and Randrianarison, R. M. 2007. Influences des Pressions Anthropiques sure les Lémuriens d'Antantaka, dans la Partie Est du Plateau de Makira, Maroantsetra, Madagascar. Madagascar Conservation & Development 2,1: 21-27.

Southall, A. 1986. Common themes in Malagasy culture. In: Madagascar: Society and History. C. P. Kottak, J.-A. Rakotoarisoa, A. Southall and P. Vérin (eds.), pp 411-426. Carolina Academic Press, Durham, N. C.

Community-based management in two biosphere reserves in Madagascar – distinctions and similarities: What can be learned from different approaches ?

Nadine V. M. Fritz-Vietta[I], Christiane Röttger[II] and Susanne Stoll-Kleemann[III]

Correspondence:
Nadine V. M. Fritz-Vietta
Ernst-Moritz-Arndt-Universität Greifswald,
Friedrich-Ludwig-Jahnstr. 16, 17487 Greifswald, Germany
E-mail: nadine.fritz-vietta@uni-greifswald.de

ABSTRACT

This article explores the socio-cultural aspects of community-based management of natural resources in Madagascar. The contractual devolution of management rights and responsibilities to local user groups constitutes an important instrument in the country's environmental policy. Its challenges and opportunities are investigated through a case study that scrutinizes two biosphere reserves: Mananara-Nord at the northeast, and Sahamalaza at the northwest coast of Madagascar. While Mananara is relatively well established, having successfully realized more than twenty management transfers, implementation in Sahamalaza is still in its infancy. Comparing both sites allows for drawing a picture of major factors that influence the success of this instrument. Data was gathered using a qualitative social research approach based on interviews and participatory rural appraisal. A conceptual framework integrating informal institutions and the concept of social capital was used to better understand socio-cultural dynamics within rural communities.

The paper presents the characteristics of both sites and explores traditional natural resource use, local associations, and their role in collective action, as well as customary institutional arrangements. The results provide insight into strengthening local management capacities and cooperation. They also highlight the need to leverage local knowledge and to reconcile the different formal and informal rules for active and responsible involvement of concerned community members in sustainable resource management.

RÉSUMÉ

En tant que nation, Madagascar qui est très diverse à tous égards, lutte pour se stabiliser politiquement. Au cours des dernières années, l'orientation des politiques environnementales semblait claire et poursuivait le but consistant à promouvoir l'utilisation durable des ressources naturelles afin de réduire la pauvreté tout en assurant le développement du pays. L'approche présentée dans cet article repose sur la gestion des ressources naturelles par les communautés rurales. Deux réserves de biosphère ont été retenues pour être considérées dans une réflexion sur les aspects essentiels qui influencent le processus de décentralisation au niveau local. Les processus de la gestion communautaire des ressources naturelles sont nettement distincts dans leur application entre la Réserve de Biosphère Mananara-Nord, située sur la côte nord-est du pays, et celle de Sahamalaza Iles-Radama, située sur la côte nord-ouest. Il existe cependant des conditions similaires qui permettent d'établir une comparaison et de présenter une image détaillée des transferts de gestion qui prennent place dans les deux études de cas.

Le transfert des droits d'usage et de gestion des ressources naturelles, lorsque l'État reste propriétaire, vise à augmenter la responsabilité de la population locale. Les terrains ainsi transférés sont surtout ceux qui bordent les Parcs Nationaux afin d'établir une ceinture verte dans laquelle les ressources seraient utilisées de manière durable pour satisfaire les besoins essentiels de la population locale. Dans le cadre d'un processus de transfert, un contrat est établi qui facilite l'allocation limitée des terrains aux communautés locales sous l'auspice d'une association civile.

Les conditions socioculturelles des deux réserves de biosphère étudiées sont analysées par le biais d'une méthode empirique de recherche en sciences sociales. Celle-ci est basée sur des interviews semi-structurées avec des gestionnaires des réserves, des représentants des résidents et des autorités, ainsi que sur la Méthode Accélérée de Recherche Participative (MARP) réalisée auprès des associations locales.

L'article présente le contexte et les caractéristiques des deux études de cas, repose sur l'utilisation traditionnelle des ressources naturelles, les associations locales et leur rôle dans l'action collective sur la conservation et l'éducation environnemental ainsi que les structures institutionnelles et les coutumes locales. Le concept de capital social est appliqué afin de permettre une meilleure compréhension des dynamiques socioculturelles des communautés locales concernées. Notre étude comparée permet de mettre en exergue des similitudes importantes entre les deux sites, malgré leur diversité, ainsi que d'identifier des approches de gestion intéressantes qui indiquent diverses voies pour améliorer leur situation. Nos résultats reflètent l'importance d'intégrer des règles formelles

[I] GoBi Research Group, Sustainability Science and Applied Geography, Phone: +49 3834 86 4682
[II] Humboldt Universität zu Berlin, E-mail: christianeroettger@hotmail.com
[III] GoBi Research Group, Ernst-Moritz-Arndt-Universität Greifswald, Sustainability Science and Applied Geography, Friedrich-Ludwig-Jahnstr. 16, 17487 Greifswald, Germany, Phone: +49 3834 86 4680

et informelles comme les *dina* et *fihavanana* (institutions informelles) dans l'utilisation des ressources naturelles, par exemple dans le contrat officiel de transfert de terrains. De plus les activités collectives de gestion favorisent une compréhension globale qui permet d'attirer d'autres membres de la communauté pour participer à l'effort collectif. L'étude détaillée de ces deux cas illustre clairement les enjeux et les occasions à saisir dans le transfert des décisions ainsi que les tâches à réaliser pour la décentralisation de la gestion des ressources naturelles à Madagascar ou ailleurs.

KEYWORDS: Community-based natural resource management, biosphere reserve, decentralization, informal institutions, local associations, Madagascar, social capital.
MOTS CLEF : gestion communautaire des ressources naturelles, réserve de biosphère, décentralisation, institutions informelles, associations locales, Madagascar, capital social.

INTRODUCTION

Madagascar, well known for its majestic natural beauty, finds itself in the midst of a struggle. After the coup d'état in March 2009, its political direction is unclear. Beginning in the 1980s, the government initiated Africa's first Environmental Charter leading to an ambitious and comprehensive environmental program, the National Environmental Action Plan (World Bank/Coopération Suisse/UNESCO/UNDP/WWF 1988). The Plan was given legal power in 1990 and has being carried out in three different phases, each lasting five years (Gezon 1997). The current instability of the government, however, threatens to set back these efforts towards sustainable development and conservation by years. Nevertheless, people involved in the management of these areas have demonstrated their willingness to continue with what has been established over the past few years. Building on such local confidence, our aim is to introduce interesting cases that demonstrate the implementation of community-based management concepts for the integration of nature conservation and development in a sustainable manner. In this article, we rely on the cases of two biosphere reserves: Mananara-Nord on the northeast coast and Sahamalaza Iles-Radama on the northwest coast. They apply different approaches, but have the same goal: The preservation of valuable ecosystems and the support of local livelihoods.

Madagascar has developed specific policies for delegating management rights for natural resources to local user associations. This kind of community-based natural resource management (CBNRM) is meant to foster local people's responsibility and raise their awareness of the value of conservation (Wainwright and Wehrmeyer 1998). In 1996, the first law on the co-management of natural resources was developed, the *Gestion Locale Sécurisée* (GELOSE). It is applicable to all natural resources and aims at better environmental stewardship through the establishment of local management entities, formal institutions, and empowerment. A central element of GELOSE is the contracts negotiated among the state (the forest authority), the municipality (e.g. the mayor), and a voluntary association of community residents, the *Communauté Locale de Base* (CLB) created for this purpose (Antona et al. 2004). For forests, a special legislation was formulated in 2001, *Gestion Contractualisée des Forêts* (GCF). The GCF process is a simplified alternative for the transfer of forest management rights to local user groups, called *Communauté de Base* (COBA) (Kull 2002, Raik and Decker 2007).

Currently, more than 450 GCF and GELOSE contracts have been signed throughout Madagascar (Raik and Decker 2007, GTZ and MEEFT 2008). Often, conservation and development organizations play a central role in designing management plans, zoning the areas, and providing technical support to the COBA/CLB. Although people receive the formal right to use resources in defined areas for their own purpose, the question remains how they can make use of the adjudicated resources to improve their livelihoods. As Salafsky and Wollenberg (2000) articulate clearly, "... having at least moderate linkage between the biodiversity and the livelihood activity, the strategy also requires that the project generates cash and non-cash benefits for the stakeholders and that the stakeholders have the capacity to take action to mitigate internal and external threats" (Salafsky and Wollenberg 2000: 1435).

The Convention on Biological Diversity (CBD), signed by the Malagasy government in 1996, confirms this sentiment. The implementation of the CBD supposes the involvement of all sectors of society in the conservation of biological diversity and sustainable resource use (UNESCO 2000). This idea is formulated in the vision of the biosphere reserve concept established by UNESCO's Man and the Biosphere (MAB) Programme. Currently, 553 sites in 107 countries have been declared as biosphere reserves (UNESCO 2009). These reserves have three inter-connected functions: (i) Conservation (landscapes, ecosystems, species, and genetic variation); (ii) development (economic, human, and culturally adapted); and (iii) logistic support (research, monitoring, environmental education and training) (UNESCO 1996). To implement the three-fold functions, biosphere reserves ideally consist of three interrelated zones: The core, buffer, and transition zone. The conservation efforts inside the core zone together with development activities in the buffer and transition zones are meant to attract the support of local populations living adjacent to the core zone.

Integration of local communities in management activities is an important objective in the two biosphere reserves where the implementation of community-based management has started. However, the status quo and the approaches differ between sites. In this article, we highlight similarities in both areas and contrast what has been achieved. Inspired by Pretty (2003), who depicted the theoretical developments of commons governance and social capital in relation to collective management of resources, we seek to link relevant factors with the concept of social capital. Thus, the focus is on the role and potential impact of cultural factors and social structures within the communities on the success of these initiatives.

CONCEPTUAL FRAMEWORK FOR UNDERSTANDING INFORMAL INSTITUTIONS. In contrast to the common use of the term 'institutions' as a synonym for 'organizations', institutions in this context are defined as rules of game, the "commonly understood rules and norms that stipulate what actions are required, permitted, or forbidden in particular situations" (Poteete and Ostrom 2002: 5). Organizations, on the other hand, are the "players of the game" (North 1994: 3). A distinction can be made between informal and formal institutions, the latter being legally recognized. Informal institutions are the traditions, customs, cultural norms, values, beliefs, and social behaviors, which also have great influence

on the structure and development of a society (North 1994, Williamson 2000). The New Institutional Economics analyzes the relationships and interdependences of institutions, the affected agents, and the resource base on which they depend (Paavola and Adger 2002). These societal relationships and structures are given special recognition in the concept of social capital, which is of particular relevance for this study. The most important introductory work on this concept has come from Bourdieu (1986), Coleman (1988), and Putnam et al. (1994). According to Putnam (2000), social capital refers to "connections among individuals – social networks and the norms of reciprocity and trustworthiness that arise from them" (Putnam 2000: 19). Social relations are, therefore, an outcome of reciprocity. He goes on to distinguish three categories: bonding, bridging, and linking social capital (High et al. 2005). Bonding social capital refers to ties between individuals with similar characteristics, such as family and close friends. Bridging capital designates more distant social networks and associations with individuals from a different social background but with shared interests. Linking social capital reaches outside the community across group boundaries and involves a vertical, hierarchical connection (Putnam 2000).

Social capital explicitly recognizes and analyzes informal institutions, and its potential to enable a better understanding of the informal processes is obvious. Formulating the three categories of social capital allows a comprehensive analysis of the interactions and relationships between groups and individuals at different levels as well as the nature of such relations (High et al. 2005). It thus offers the opportunity to examine a community's social orientation toward fragmentation (associated with strong bonding capital), cooperation (high bridging capital), and hierarchy and power structures (associated with linking capital). This conceptual framework is used as an analytical lens to better understand the social and cultural dynamics of rural community associations and their participation and performance in community-based management projects within rural villages.

METHODOLOGY

Our primary research question was "What are the conditions for community engagement in conservation and sustainable resource use in the two Malagasy biosphere reserves?" To answer the question from a socio-cultural perspective, we consider a qualitative case-study approach adequate. This allows for inter-subjective insight into the social reality of a particular situation (Flick 2007) that can be transferred to other cases with similar conditions and comparable challenges. For the analysis of socio-cultural aspects, a qualitative approach fits better than a quantitative one, as the latter seeks to abstract a unified set of principles from representative variables (Punch 2005). Generally, case studies are applicable for an investigation of crosscutting issues in as many different dimensions as possible (Denzin and Lincoln 2003). This requires openness and flexibility, which we achieved through a triangulation of perspectives (Flick 2008), i.e. (1) observation and interrogation from the point of view of two researchers, (2) application of different data collection methods, (3) investigation of two different sites, and (4) one site at two different points in time.

Data collected during two field visits in 2005/2006 (four months) and 2008 (six weeks) provide the analytical basis. During the first stay in the Mananara-Nord Biosphere Reserve, we gathered extensive insight into local conditions, cultural backgrounds, and management practices (Fritz-Vietta et al. 2008, Fritz-Vietta and Stoll-Kleemann 2008). We identified relevant stakeholders and key success factors for biosphere reserves, analyzing 64 semi-structured interviews (21 conservation and/or development professionals, 15 protected area managers, 28 locals) and 36 questionnaires filled out by all interviewees except the locals. We also undertook a comprehensive literature review. Analogue to the qualitative paradigm of a circular research process (Flick 2007), during the second stay, we focused on one of the key factors, i.e. community-based management. For the case study undertaken in 2008, we chose two study sites (Mananara-Nord BR and Sahamalaza Iles-Radama BR) to encompass different examples in comparable set-ups.

Through theoretical sampling, we determined whom to interview as well as the number of interviews necessary for relevant and comprehensive data (Glaser and Strauss 1967). Hence, interviews and meetings were undertaken with representatives of CLB/COBA of villages, which were in different stages of organization and GELOSE/GCF implementation, as well as with members of other associations, local authorities and farmers. Questionnaires were handed out to management staff of the Biosphere Reserves to gather information on collaboration partners and their point of view on community-based management. In the field, we conducted 35 semi-structured interviews of which ten were with experts, seven with management staff (four in Mananara, three in Sahamalaza), 18 with locals (six in Mananara, 12 in Sahamalaza).

In addition, we carried out field observation by visiting local villages (six in Mananara-Nord and seven in Sahamalaza) and traversing the areas' core, buffer, and transition zones. Participatory rural appraisal methods with 16 different local associations (COBA/CLB), women groups, Slow Food (representing farmers cultivating certified organic vanilla in the Mananara-Nord Biosphere Reserve, www.slowfood.com), and representatives of the platform *STRUCTURE* (in Sahamalaza) were applied. For two exercises, we chose a resource map (including the identification of particular forest values) and collaboration map, the former providing insights into the perception of local people's surroundings and the latter giving an understanding of the collaboration network among the actors involved. Where possible, we went on transect with the community members to understand their drawings. During enquiries among local people, communication was facilitated through translators. Ten expert interviews with conservation and development specialists provided an additional perspective on the issue. The analytic process was accompanied by several detailed literature reviews of both scientific papers and local reports and publications.

Interviews were transcribed verbatim, and the software ATLAS.ti facilitated the analytical process. Quotations cited in the article are drawn from this computer-based analysis. In the analytic process, we contrasted the theoretical concept of social capital with our findings in order to identify patterns and define cohesion.

CONDITIONS ON THE GROUND

CHARACTERISTICS OF THE MANANARA-NORD BIOSPHERE RESERVE. The biosphere reserve, designated by Presidential Decree 89/216 on July 25, 1989, is located on the

northeast coast of Madagascar. It is part of the Analanjirofo region and is situated 280 km north of the former provincial capital city, Toamasina. The total area encompasses 140,000 ha, including a strict conservation area comparable to the core zone of the MAB concept, which includes the remaining parts of the rain forest and coral reefs. This zone is officially categorized as a national park (Commission SAPM 2006) equivalent to International Union for Conservation of Nature (IUCN) category II (Dudley 2008). The 23,000 ha core zone comprises three massive primary forest blocks as well as a marine park of 1,000 ha surface area, including three islands (ANGAP/UE/IC 2005). The core area is surrounded by the peripheral or development zone – *Zone de Protection and Zone Périphérique* in the Malagasy terminology – in which the sustainable use of natural resources by the local population is permitted (see Figure 1). The buffer zone (according to the MAB approach) is now being established with the management transfer of forest areas located around the core zone. Overall, the ecosystems in the biosphere reserve are very diverse and include tropical humid forest, sandy coastal plains with littoral, and wetland vegetation, mangrove formations, marshlands, and coral reefs (UNESCO/ANGAP/DEC 2001).

Originally, between 1989 and 2002, the Mananara-Nord Biosphere Reserve was managed and financed by UNESCO. It was established as a conventional Integrated Conservation and Development Project (ICDP) with the aim to achieve nature conservation through the support of local livelihoods (Wells et al. 1992). Despite successes in economic development, the local population did not relate these development efforts with the ultimate goal of conserving their environment. Thus community-based natural resource management should refine the orientation toward a more integrated approach.

In 2002, the management of the Biosphere Reserve was assigned to the Madagascar National Parks (MNP) formerly known as ANGAP (*Association Nationale pour la Gestion des Aires Protégées*) and was funded by the European Union until 2009. Due to this European funding with a budget of more than twice the common average in developing countries (James et al. 1999), the management has been well equipped with a vehicle fleet, computers and radio communication. The staff input corresponds to the average in African countries (with 30.5 permanent, 20 for administrative support and four non-permanent employees) (James et al. 1999). The management includes three levels: (i) The coordination and administrative level, (ii) the conceptual and methodological level, and (iii) the operational level. Staff working in levels one and two are based mainly in the head office in the local capital, Mananara-Nord, while they work closely with the staff responsible for the execution of management activities (third level). The Biosphere Reserve is divided into five spatial sectors, each supervised by one coordinator (*Chef Secteur*), who regularly reports to the Biosphere Reserve director (level one). Rangers assigned to each coordinator traverse their sectors for several weeks at a time, carrying out awareness-raising activities and surveillance; they also try to reach very isolated territories. They meet regularly with their *Chef Secteur*. This sectoral approach reduces spatial distances to facilitate collaboration with local associations (Fritz-Vietta and Stoll-Kleemann 2008). Next to the prevalent conservation activities, the management focuses its development activities on support in agricultural productivities, local rural infrastructure, animal husbandry, handcraft and the advancement of women as well as the establishment of eco-tourism and the cultivation of certified organic vanilla as alternative income sources (ANGAP Réserve de Biosphère Mananara-Nord 2003).

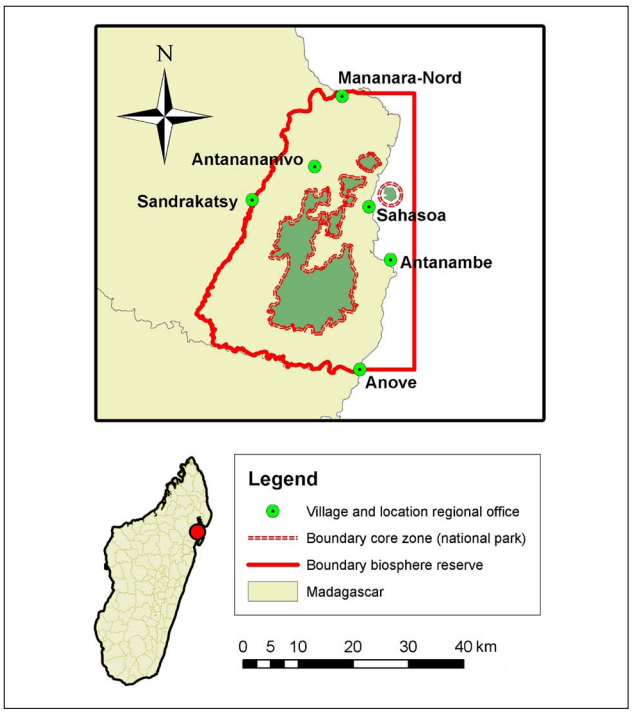


FIGURE 1. Mananara-Nord Biosphere Reserve.

CHARACTERISTICS OF THE SAHAMALAZA ILES-RADAMA BIOSPHERE RESERVE. The marine and coastal protected area Sahamalaza Iles-Radama was declared as a biosphere reserve by UNESCO in September 2001. Six years later, in March 2007, the core zone of the Biosphere Reserve was declared a national park within the national protected area network (Commission SAPM 2006), corresponding to category II of the IUCN protected-area classification (Dudley 2008). In 2006, Madagascar National Parks was officially designated to manage the area.

The Biosphere Reserve encompasses a total area of 153,200 ha (of which 26,035 ha comprise the core and buffer zone, i.e. the national park) including the Bay of Sahamalaza, which covers the Sahamalaza Peninsula and coral reefs and the Radama Archipelago, which is composed of four islands. It is situated at the northwest coast of Madagascar between the Bays of Narinda and Mahajamba in the south and Ampsindava and Ambanja – Nosy Be in the north. It covers five communes: Ambolobozo, Befotaka, Anorotsangana, Ankaramibe, and Maromandia. (SAVAIVO 2003, ANGAP and MEEFT 2008) (Figure 2).

The Biosphere Reserve was managed and co-financed by a consortium formed by the Wildlife Conservation Society (WCS) and the *Association Européenne pour l'Etude et la Conservation des Lémuriens* (AEECL) in collaboration with Madagascar National Parks (MNP) from its creation in 2001 until 2007, when WCS left the region. Today, the Biosphere Reserve (BR) is managed by three parties: The regional office of the environmental ministry *Direction Régionale de l'Environnement et Forêts* (DREF), the local MNP office in Maromandia, as well as the regional MNP branch in Mahajanga. The management staff of the national park (MNP Maromandia) is composed of a director, the head of the financial department, and two *Chefs Secteur*, whose tasks

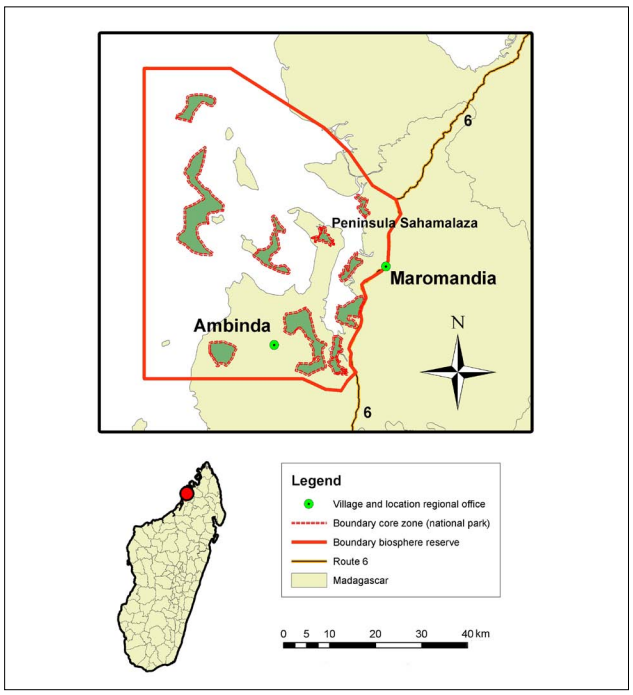


FIGURE 2. Sahamalaza Iles-Radama Biosphere Reserve.

are comparable to those described for the Mananara-Nord BR. The management does not employ its own rangers, but rather depends on assistance from local people, who are remunerated for surveillance services. AEECL carries out research and facilitates training on agricultural methods. The national NGO *Service d'Appui à la Gestion de l'Environnement* (SAGE), funded by the United Nations Development Programme (UNDP) and the Global Environmental Fund (GEF), installed in Sahamalaza in 2007 to support the implementation of the management transfer (ANGAP and MEEFT 2008). Its one-person office in Maromandia however, is underequipped and remains rather inactive.

Financial support is provided by GEF/UNDP, but is intended to run past in 2009. As a result of the political crisis, the funding has already been reduced to core activities of management and conservation. Negotiations to mobilize further funding after 2009 are currently under way within PNM. Inadequate facilities constrain the management performance as do the lack of stable electricity, basic infrastructure, electronic equipment, and means of transportation.

LOCAL PEOPLE'S INVOLVEMENT IN NATURAL RESOURCE MANAGEMENT

TRADITIONAL NATURAL RESOURCE USE AND CULTIVATION.

People are particularly dependent on the collection of natural resources in both the Mananara and Sahamalaza Biosphere Reserves. Forest resources are indispensible for house construction, carpentry, handcraft, basketry, and firewood. Canoes and the mortars and pestles used to grind food are made of wood extracted from the forests. Medicinal plants and fruits are used for health care and nutrition, as are some small animals such as the common tenrec (*Tenrec ecaudatus*) in Sahamalaza and the flying fox (*Pteropus rufus*) in Mananara. The principal marine resources exploited in Mananara are mussels, squid, and sea cucumbers and in Sahamalaza sea cucumbers, sharks, lobsters, and crabs. Whereas the use of forest resources is primarily for subsistence purposes, water resources are exploited for both personal and commercial use. Fishing is poorly regulated, and the encroachment of foreign fishing boats is to the detriment of local fishermen and the marine fauna. The absence of infrastructure and the difficulty of communication marginalize villages in both regions and can lead to an increase in illegal exploitation of natural resources. Moreover, local people are often forced to accept low prices by commercial traders.

In rural areas, most Malagasy households generally do not possess more than a small cottage, a small piece of agricultural land for cultivation, and – if they are relatively well off – a small amount of livestock. When not commercially exploited, livestock predominantly serve as security in times of scarcity. Cultivation for subsistence and the collection of natural resources provide the basis for rural livelihoods. Agriculture in Sahamalaza is rendered difficult by a chronic lack of water, the absence of a well-established and well-functioning irrigation infrastructure, and a dearth of flatlands that could be used for irrigated agriculture. Therefore, slash-and-burn agriculture, called *tavy,* is the dominant method employed. Typically, an acre or two of forest is cut, burned, and then planted with rice. After a year or two of production, the field is left fallow for four to six years before the process is repeated. The more often *tavy* is performed, the more the soil becomes exhausted of nutrients and the land likely to be colonized by scrub vegetation or alien grasses; the local name for this secondary vegetation is *savoka* (Erdmann 2003). On slopes, the new vegetation is often insufficient to anchor soils, making erosion and landslides a problem (Kistler and Spack 2003). However, the local population has been practicing *tavy* as a traditional agricultural technique over the centuries without having a markedly negative effect on biodiversity (Erdmann 2003, Raik 2007). Today, the increasing population contributes to the destructive effect of *tavy*, as the pressure on land has grown, cultivable land is limited and people are not able to wait for the soil to regenerate, with the result that they have increasingly turned to the exploitation of new, pristine areas.

In Sahamalaza, *tavy* is still practised on a considerable scale. Some local people appear to realize the negative effects of the practice, as it was explained by one villager, "Protecting nature was already in my mind, but the aggradations of our paddy fields come from the river of Monambaro, where there is a lot of erosion and landslides, favoring the aggradations of our paddy fields." (local resident, BR Sahamalaza, quote 26: 11).

Throughout the interviews with local residents, it became evident that *tavy* is not only a method for cultivation. It also has cultural significance, as it traditionally defines to whom a site belongs. Throughout Madagascar's history, land reclamation has been an informal process: A person is recognized as the owner of public land provided that it had not previously been cultivated by someone else (Jacoby and Minten 2005). Clan leaders called *fokonolona* represent traditions and customs such as the clan leadership structure and taboos (Tengö et al. 2007) and play a central role in land allocation. A local resident in Sahamalaza described the informal process: "After I arrived here, I went to the *fokonolona* and they gave me this land, and after an integrated occupation, I became the owner, and I could legalize it at the *fokontany*." (local resident, BR Sahamalza, quote 21: 29). Property rights have been neither precisely clarified nor codified. In Mananara *tavy* increased considerably since the beginning 1970s, when General Ramanantsoa liberalized land

tenure for appropriation through *tavy*. People clear-cut various primary forest patches to occupy as much land as possible (ANGAP-UE/IC 2005). Following the establishment of the Biosphere Reserve, however, deforestation by *tavy* has dropped significantly (cf. Conservation International/Ministère de l'Environnement, des Eaux et Forêts/USAID 2007). This is particularly noticeable in the core zone, i.e. the national park, where monitoring demonstrated the absence of *tavy* in the last few years. An associate of the management explained, "The flyover (…) confirms that there is no *tavy* anymore. Our technical consultant was very sceptical before looking at the pictures [and asked] 'Are you sure that there is no deforestation anymore?' because our reports state that the deforestation has stopped. But after looking at the photographs, he [the consultant] confirmed [that our observations were correct]." (staff member, BR Mananara-Nord, quote 41: 1).

In Sahamalaza many *Communauté Locale de Base* (CLB) members who are convinced of the need to protect their remaining natural resources complained about the tendency of others to be ignorant and only interested in their own well-being and not in that of the whole society. One person explained: "Those who do not want to become member of the CLB are still the majority. (…) They only look for their individual interest but not for the society's. And then they say, 'I will do this, even if the CLB does not give me the permission to clear the forest. I will go to the *Chef Cantonnement* and I will do what I want to do.' And the law so far does not stop him." (local resident, BR Sahamalaza quote 20: 37).

In both biosphere reserves, most of the land is officially state property. Two approaches are applied to overcome the unregulated occupation of land and the use of natural resources. First, the Malagasy government, in collaboration with MNP, developed the national protected areas legislation *Code des Aires Protégées* (COAP) (latest version from November 2008, which yet remains unsigned due to the political struggle). This law defines specific zones – a buffer zone (*Zone d'Occupation Contrôlée* (ZOC) and a *Zone d'Utilisation Contrôlée* (ZUC)) surrounding the core zone – in which controlled resource use is permitted to reduce human-induced pressures on protected ecosystems. Both biosphere reserves include ZUC in their zonation, whereas ZOC is not applied since there are no permanent settlements in either of the two national parks. Secondly, in line with the transfer of resource management according to *Gestion Locale Sécurisée* (GELOSE) policy, the decree called *Sécurisation Foncière Relative* (SFR) comes into force in order to enhance tenure security (Decree n° 98-610 of 13 August 1998). It involves a property-rights registration process that defines boundaries for formally allowed resource use, though it cannot be considered as proper cadastre (Belvaux and Rabearisoa 2006). In practice it has been barely applied mainly due to lacking competencies (Resolve Conseil/PCP/IRD 2005). The SFR decree is not part of *Gestion Contractualisée des Forêts* (GCF) policy as to simplify the implementation process (Hockley and Andriamarovololona 2007).

The Sahamalaza Biosphere Reserve is the first protected area with core zones in the ocean. Non-local fishermen from the nearby island Nosy Be pose a threat to the marine resources through illegal fishing. Therefore, the intention is to include marine segments in the transferred lots through the GELOSE policy in order to formalize co-managed zones. In Mananara, forest use is formalized through the GCF policy. The terrains are located around the core zone and function as a 'green belt' for regulated resource use. While in Mananara most of the planned terrains have been transferred, in Sahamalaza the official process has not yet started.

THE ROLE OF LOCAL ASSOCIATIONS. To apply GCF and GELOSE policy, either two or three legal bodies, respectively, are required to sign the contract with the local grouping, which must clearly regulate the rights and obligations associated with the access to natural resources (Antona et al. 2002). A premise is that the local residents establish a legal entity in the form of an association to represent the community as a juridical person in any agreement with the government and local authority representatives. The result has been the formation of the *Communauté locale de base,* COBA (as they are called in Mananara) and the CLB (the abbreviation in Sahamalaza).

According to article 3, act 96-025, an association is "a voluntary grouping of individuals united by similar interests and obeying a common code of life". Officially, its mandate is that of a non-governmental organization (NGO) (GTZ and MEEFT 2008). Next to COBA and CLB, which are central to the decentralization process, other groups exist in both regions that represent accumulated interests. An example is the *groupes de femmes* (women's groups). In the Mananara region the groups are represented by women committed to local improvement who worked with Madagascar National Parks (MNP) to establish lodges for eco-tourists. We were hosted there for two days and experienced the women's engagement and personal involvement in their project. In addition to eco-tourism activities, they engage in social work, support school rehabilitation, and conduct AIDS-prevention activities. Men, too, participate in women's groups and are always welcome, as long as they accept the organization's rules. In Sahamalaza, the women groups are inter alia engaged in the organization of ceremonies and celebrations of environmental events, which they plan in collaboration with several green associations (including CLB).

Every year, the associations arrange events such as the World Environment Day (5 June) and the *fête des lémuriens* (26 September). The target groups are local villagers, children, and local authorities. Financially and technically supported by MNP, Wildlife Conservation Society (WCS) and *Association Européenne pour l'Etude et la Conservation des Lémuriens* (AEECL), activities like folk dance for women, sport matches for children, and poetry for everyone are offered. At the center of these activities is the sensitization with regard to reforestation programs and the change of behavior with respect to *tavy* (ANGAP 2008).

Another interesting example in Mananara is called Slow Food, an association of small-scale farmers who cultivate organic vanilla. In the course of the Biosphere Reserve's operation, this certificate of a European NGO was introduced to develop a local market for organic vanilla. The association has recorded exceptional growth in its membership, which reached 586 members in 20 different villages registered in 2007 (Association des Planteurs de Mananara/Intercoopération Madagascar/Parc National Mananara–ANGAP/Fondation Slowfood pour la Biodiversité 2008). People recognize the advantages of being a member and are grateful for technical support and the promotion of the label, but also for the chance to communicate their experiences at regular meetings. Training programs are being provided, although members complained that the frequency is still insufficient.

Whereas in Mananara the COBA work mainly independently of each other, having only occasional meetings, in Sahamalaza

an interesting concept is applied in order to foster mutual learning and knowledge transfer. A platform called the *STRUCTURE de concertation* has been established in every commune that is part of the Biosphere Reserve. These *STRUCTURES* are of formalized, official character with constituted rules and procedures (ANGAP 2008). Figure 3 illustrates the assembly of the *STRUCTURE* Moramandia (blue) and its collaboration partners (local authorities and NGOs). *STRUCTURE* allows for the coordination of various associations in order to pool those who want to manage forest and marine resources (SAVAIVO 2003).

Another instrument for the coordination of all CLB in the Sahamalaza Biosphere Reserve is a federation (*Fédération*). The president of the federation is responsible for awareness-raising activities and represents all CLB in public affairs. He also looks for partners and settles conflicts between CLB and other actors. CLB presidents meet him three times a year for inter alia training activities, which are then distributed within the associations. *Service d'Appui à la Gestion de l'Environnement* (SAGE) and NGO staff, for example, give lectures on management and sustainable resource use methods to the presidents of *STRUCTURE,* who in turn pass their new knowledge on to other members. Interestingly enough, most of the presidents are of cultural or political rank. For example, the president of *STRUCTURE* in Maromandia is member of the royal family of the region.

LOCAL INFORMAL INSTITUTIONS AND CULTURAL FACTORS.

A well-known informal institution is called *dina*, which is, traditionally, an oral code of conduct that governs relationships within and between communities. A specific instance of application of the *dina*, however, can also be formulated as a written document and then made public (Rakotoson and Tanner 2006).

The term *dina* refers to a system of local rules and regulations used to guide and control community behavior, including resource use. Under GELOSE and GCF, relevant aspects of the *dina* are formalized and integrated into the contract between the community association and the official agencies. This should help to establish and monitor the rules negotiated and fixed in the contract.

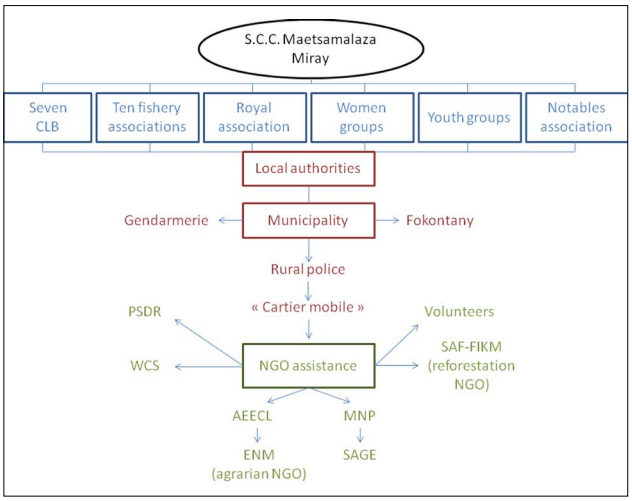


FIGURE 3. Assembly of the *STRUCTURE* Maromandia (blue) and its collaboration partners – local authoritities (red) and non-governmental organizations (green) (translated drawing by representatives of S.C.C. Maetsamalaza)

Abbreviations:
PSDR: Projet de Soutien au Développement Rural; WCS: Wildlife Conservation Society; AEECL: Association Européenne pour l'Etude et la Conservation des Lémuriens; MNP: Madagascar National Parcs; SAGE: Service d'Appui à la Gestion de l'Environnement

The *dina* can be used to regulate a wide range of issues and to solve conflicts, especially in remote areas. It is an informal legal mechanism that also stipulates fines (called the *vono dina*). Within its broad range of applications, and of specific relevance to the present discussion, the *dina* provides security over land-use practices and access to natural resources.

In an attempt to harmonize the control mechanisms of the GELOSE/GCF contract, they are incorporated in a *dina* document and the management plan. Furthermore, the responsibilities of the contract are included, involving sanctioning and monitoring activities of the CLB/COBA for the transferred resources. This ensures its acknowledgement as a legal institution with regard to resource use. The *dina* has to be published by the local mayor in order to reach official and public acceptance (Sörensen 2005). The detailed design and content of the *dina* document is negotiated and fixed during meetings of the COBA/CLB members.

In both regions, the application of the *dina* by COBA/CLB members to punish offenders of the agreement remains a challenge. While in Sahamalaza the problematic is the inadequate elaboration and implementation of the *dina*, in Mananara the foremost problem is its incompatibility with the social phenomenon of *fihavanana*. Although the *dina* have traditional legitimacy and relevance to local people, there is a risk that newly developed *dina* are perceived as externally defined and imposed rules, which do not correspond with local visions and ambitions (Keller 2009). Sahamalaza, having only relatively recently applied GELOSE, is still revising and formulating the relevant aspects of the *dina*, both on the communal and inter-communal level. In fact, the management transfer is not yet official, leaving the CLB without the legal authority to apply sanctions against delinquents. Furthermore, respondents interviewed stated repeatedly that applying the *dina* is difficult because every *fokontany* has its own local interpretation of the *dina*. A person who exploits the forest outside his own village boundaries does not feel obligated to comply with the rules of the other village. This is especially problematic when the *dina* interpretation of the two villages have different regulations concerning resource use. Conflicts may also arise when the external 'offender' is simply not aware of or has no knowledge about these differences.

CLB representatives perceive the protection of the forests to be impossible without a legally binding, detailed rendition of the *dina*. In an effort to harmonize the differences between the local interpretations of the *dina* (called *dina fototra*), the general assembly of the CLB has initiated a project to establish an inter-communal version, termed *dina kaominaly*, which would be applicable for the whole region. However, whereas the *dina fototra* are usually respected and agreed upon, the *dina kaominaly* often have less legitimacy and reflect top-down priorities, which weaken their authority and acceptance at local level (Kull 2002). All CLB and *Chefs de Fokontany* are involved in the elaboration of the *dina kaominaly*, and most CLB members stress its importance for the collective solution of the problem.

This inter-communal initiative is costly in terms of time, resources, and the general effort required to build consensus. Accordingly the process has not yet come to an end. Legally codifying the *dina* and implementing GELOSE in Sahamalaza is also constrained by a form of linking social capital, which has been stressed by almost all residents. To paraphrase one observer, the main problems with regard

to the *dina* and the management transfer are located at doorstep of the technical state service and the elected authorities because there is an inherent conflict of interest when the transfer is accomplished: namely, the technical service will lose its power. Complicating things further is the fact that the authorities are subject to manipulation by those looking to gain personal advantage.

"If the CLB manage their resources independently, the *Chef Cantonnement* and the *Direction Régionale des Eaux et Forêts* (DREF), will lose their power and personal advantages. So they destroy the forest before the transfer is realized, because afterwards, it will not be possible any longer." (local resident, quote 20: 20). This perception touches a range of issues, including corruption and the inherent problem of any decentralization process: The redistribution of power. Currently, the *Chef Cantonnement* supervises logging permissions, receives fees and relinquishes contracts or fines – all of which will be transferred to the CLB. It also illustrates the willingness of CLB members to manage their forests accountably and their frustration because their empowerment is still inhibited.

In Mananara, the problem of applying the *dina* is closely related to another social cornerstone of Malagasy society: The *fihavanana*. While the *dina* are called the "cement of Malagasy society" (Jones et al. 2008), the *fihavanana* is a system of horizontal solidarity. Dahl (1993) explains: "The root of the word is *havana*, which means parent/kin/lineage. (...) *Havana* is also used as honourable term. To be called a *havana* means that one is accepted as a family member. *Fihavanana*, therefore, means kinship, but also friendship, solidarity, readiness to help, good relationship. This meaning is expressed through many proverbs, such as "It is better to lose wealth than to lose *fihavanana*" (*Aleo very tsikalakalan-karena toy izay very tsikalakalam-fihavanana*)" (Dahl 1993: 100).

In Mananara, these strong relationships complicate the application of *dina*. "The *fihavanana* states that the *dina* should not be applied. There is some sort of contradiction between them. The *dina* determines that if someone exploits the forest without having made the demand, he will have to pay a fine, whereas the *fihavanana* says that the issue should be dealt with amicably. Concerning the transfer of forest management, the *fihavanana* forbids applying the *dina*. This means that the *fihavanana* is a tool to invalidate the *dina*." (staff member, Mananara-Nord BR, quote 29: 26). In other words, families who dislike the rules of the *dina* use the spirit of the *fihavanana* to disobey them.

Due to this manifest contradiction between the *dina* and the *fihavanana*, COBA find it difficult to protect their forests against offenders because they often have relatives or friends in the same village. As a consequence, their illegal exploitation is tolerated in order to maintain social harmony. This observation has been confirmed by several respondents.

When asked for solutions, the possibility to harmonize between the *dina* and the *fihavanana* is linked to the motivation and attitude of the local people and their willingness to cooperate. "There are those who want to make their fortune by manipulating the *fihavanana* in order to disable the *dina*. For those who are motivated and willing to collaborate, it is possible to combine the *fihavanana* and the *dina*. But those who are not benevolent will use the *fihavanana* to disable the *dina*. If he [the offender] is affected by the *dina* governing the issue, he talks about the *fihavanana*." (staff member, Mananara-Nord BR, quote 29: 27). Although this problem was not mentioned in particular in Sahamalaza, MNP employees affirmed that the problem is not only limited to the Mananara region.

According to the Malagasy philosophy, nothing happens by chance. Social norms are built on a strong mesh of specific taboos and traditional patterns of behavior. Taboos are grouped under the term *fady* (Box 1) and have great impact on forest utilization, agriculture, and fishing activities. There are certain days that are *fady*, meaning, for example, that snorkeling is forbidden on Thursday in Sahamalaza, and that it is not allowed to cultivate rice fields on Tuesday, Thursday, and Sunday in Mananara. When asked about local customs concerning natural resources, it is the *fady* that is mentioned most often and referred to as the traditional way of resource management, a sort of "automatic conservation" (local resident, quote 20: 34). "Yes, the custom is a system to protect the environment, for example the *fady*. (…) Because if a certain area is *fady*, it is impossible to enter it. There are also animals that are *fady*, and it is forbidden to eat them, such as the lemurs, the eagles, the wild pigs, …" (local resident, Sahamalaza BR, quote 27: 25).

Both biosphere reserves include sacred places where it is strictly forbidden to cut trees and to exploit resources, each having its own history and associated traditional rules. In general, these areas are located within the remaining splits of the natural forest. However, although these traditional norms are largely respected, the younger generation no longer maintains traditional norms absolutely. Due to an individualization process and the strong influence of Western culture in recent years, especially in the context of land-reclamation and agriculture, traditions are being increasingly ignored (Raondry et al. 1995).

With regard to traditional hierarchies and cultural power relations, another interesting feature is the local royal family, the *Ampanjaka*. The region is part of the northern realm of the *Sakalava* queen, whose palace is located in Analalava (ANGAP and MEEFT 2008). The role of the monarch is illustrated in the following statement of one CLB resident: "The king has no function or responsibilities, but he is there to respect the tradition/custom …. He is the liaison between the Lord and the people (…) The word of the king is respected by the people. He is helpful in transmitting the message of the protection of the

BOX 1: *FADY*.

Taboos regulate life in the community and establish norms for what is prohibited or allowed. Some *fady* refer to places; some can refer to people (Dahl 1993). "To respect *fady* is to respect world order. *Ota fady*, to break *fady*, is dangerous. You will have *tsiny* [blame] and most probably be hit by tody, the retaliating force (...). Disrespect might block communication. Taboo-breakers are a disgrace to their home and community, as they bring the whole community out of the normal status and into a dangerous position." (Dahl 1993: 79) Dahl gives various examples of land-use projects that have failed due to a lack of respect or knowledge of local *fady*. For such projects to be successful, understanding local customs is essential, as *fady* on land can also be lifted.

environment because then, people cannot refuse. He has a lot of power." (local resident, BR Sahamalaza, quote 18: 40).

In Sahamalaza, the prince of Maromandia was very supportive when the Wildlife Conservation Society (WCS) and *Association Européenne pour l'Etude et la Conservation des Lémuriens* (AEECL) started the initiative to establish the protected area. However, when he realized that the envisioned protection zone would include part of the mangroves that he personally used for exploitation, he started to oppose the activities, according to an environmental consultant of the Sahamalaza BR. His opposition led to reduction of the population's acceptance. The situation turned again when a change of one of his ministers led to the prince once again displaying a more favorable attitude. His sister (a princess) holds a very supportive attitude towards conservation, having a close relationship to one of the *Chef Secteur*. The princess is also president of the *STRUCTURE* in Maromandia. Furthermore, the royal family also has duties, as pointed out by the local *Chef de Fédération*, who is himself a prince: "The mandate of the king is unlimited, but it depends on his health condition. He can also be deposed as a result of his behavior towards the population. The king also has to follow the rules." (quote 21: 19).

SOCIAL CAPITAL AND LOCAL INSTITUTIONS

Various factors have been presented that are associated with community-based natural resource management in both biosphere reserves. Pretty (2003) named conditions necessary for effective participation of local associations or groupings in resource management:

- Good knowledge about local resources
- Appropriate institutional, social, and economic conditions
- Processes that encourage careful deliberation

Common rules, norms, and sanctions are meant to be the drivers that ensure complementarities of group interests with individual needs (Pretty 2003). In Malagasy rural societies, cultural values and everyday life are closely interlinked with the environment.

THE ROLE OF SOCIAL CAPITAL IN COMMUNITY MANAGEMENT. Analyzing informal institutional systems and the social capital of Malagasy rural communities helps to better understand local dynamics and the occurrence of collective action. Both biosphere reserves show all three types: Bonding, bridging, and linking social capital. Community engagement in both regions depends to a large extend on the local informal institutions and their relationships. In Table 1, we list dominant institutions that characterize the social capital of local people in both biosphere reserves.

Bonding social capital: *Fihavanana* clearly shows characteristics of bonding capital, which refers to strong social ties between people with common demographic characteristics, such as family (Dahal and Adhikari 2008). The cultural identity and norms associated with *fihavanana* have great influence on the behavior of groups and individuals within communities in both positive and negative ways. On the one hand, these bonds can facilitate collective action, as it fosters mutual dependence, trust, and reciprocity. In addition, shared norms can promote conservation by prohibiting certain actions (*fady*) and by promoting cooperative decision-making (*dina*) (Agrawal and Gibson 1999). On the other hand, the traditional norms and strong personal relationships and solidarity are often used in favor of elites (Dahal and Adhikari 2008). This becomes especially obvious with regard to the traditional hierarchy and the role of the royal family in Sahamalaza. Those in a traditional leadership position such as the local kings and princes are likely to be dominant and exploitive for their own advantage. Their support, however, can trigger positive incentives for resource conservation and can function as mediation between the other types of social capital.

Bridging social capital: The collaboration between associations can enhance bridging capital, as it helps to create networks of collaboration and interactions between non-homogenous groups. Local associations are not only a major part of the decentralization policy; they also play an important role in bringing people together and in creating a favorable environment for collective performance.

In regard to the complexity of the management transfer and decision-making processes, it is essential to identify the motives behind local people's participation and the ways in which responsibility and engagement for the environment can be promoted (Agrawal and Gibson 1999, Stoll-Kleemann and Welp 2006). According to Ascher (1995), a community is composed of individuals who share particular characteristics. Associations represent the common interests of its members and stimulate shared visions through, e.g. joint activities, as can be seen with regard to the work of the women groups. Their organization of the celebrations for the 'Environmental Day' is very successful and popular. Members of associations can actively push their concerns and more easily achieve their (common) objectives. The progress made by Slow Food illustrates the power local groups can generate and how their co-operation results in successful activities and benefits for all.

Decreasing respect of traditional norms, however, can have a negative impact, as it often leads to inadequate acceptance of the CLB and indifference or even opposition towards new processes and initiatives undertaken by the associations. When people do not respect social values and common informal arrangements, individual action is more likely to succeed. Here, the importance of the local association president's qualities and reputation is apparent since he/she frames the association and is responsible to provide impulses for common action.

The coordination of CLB by the umbrella association *STRUCTURE* in Sahamalaza facilitates a network of knowledge exchange and offers a common ground for discussing problems and experiences, thereby enhancing valuable bridging social capital.

Linking social capital: Linking capital involves relationships on the vertical level, which can result in power structures' unfair exploitation of the situation and other types of corruption. Especially in Sahamalaza, the GELOSE implementation process has stagnated due to issues at the higher administrative level. According to most interviewees, it is the *Chef Cantonnement* who is blocking this process. He is in charge of issuing permissions for forest exploitation; should this responsibility been shifted to the CLB he might lose power and income opportunities. This and the traditional land allocation through *tavy* both refer to linking capital. An implementation of either GCF or GELOSE policy and – in terms of the national parks – the implementation of COAP policy empowers local associations both to reduce centralized power

TABLE 1. Contrasts in the social capital of the biosphere reserves.

Biosphere reserve → / Social capital ↓	Mananara-Nord	Sahamalaza
Bonding capital	*Fihavanana* (relationships and solidarity between family and kinship) *Fady* (shared norms and values/beliefs/taboos) Informal *dina* (on village level)	*Fihavanana* (relationships and solidarity between family and kinship) *Fady* (shared norms and values/beliefs/taboos) Informal *dina* (on village level) *King* (spiritual leader)
Bridging capital	Green associations and their organized activities COBA – management and use of transferred forest areas Slow Food – income generating activities Women's groups – social and environmental engagement Fishery associations – traditional fisheries	Green associations and their organized activities CLB – management and use of transferred forest and marine areas Fishery associations – traditional fisheries Women's groups – social and environmental engagement Royal association Youth groups Association of notables Coordinating umbrella associations (*STRUCTURE*, *Fédération*)
Linking capital	*Tavy* (informal land allocation) GCF (devolution of power, transfer of forest management-fomalization process) COAP (defined utilization zones for sustainable practices – ZUC, ZOC)	*Tavy* (informal land allocation) GELOSE (devolution of power, transfer of natural resource management – formalization process) COAP (defined utilization zones for sustainable practices – ZUC, ZOC) Inter-communal *dina* (network building between village-level and communal *dina* – harmonization)

and to influence interpretation of informal property rights. Another aspect of linking capital can be seen in Sahamalaza, where local village-level *dina* are to be developed in order to fit with the overall communal *dina*. This opens the *dina* regulations beyond the community-level and introduces a vertical dimension. Moreover, the harmonization and integration of the various local *dina* establish connections between communities, which contributes to bridging capital.

DISCUSSION

The data collected during field investigations suggest that there is enormous potential for the management transfer to empower local people and promote their participation in local associations. However, whether this potential can be fully tapped depends on several key factors.

Comprehending and effectively using socio-cultural dynamics within communities to enhance local engagement in conservation requires a wide range of (intra-cultural) social competencies, including empathy, patience, and commitment. One of the most critical success factors is the reinforcement of local capacities, especially those of local associations, but also of rangers and management staff. Regular training to improve management capabilities is essential for local associations to establish themselves as well-functioning and persuasive entities. The *Chefs Secteur* usually have a good relationship with local people, and their commitment and familiarity with the area is essential to involve local people. However, sufficient training and equipment is a prerequisite. In Sahamalaza, the lack of basic equipment poses major constrains to management performance.

Providing a secure environment for planning and collective activities is another central consideration. Recurring events and a shared vision for a common future create a sense of collectivity and reciprocity. This requirement must be accompanied by appropriate incentives such as access to markets like with Slow Food, and the participation in social events to attract those who are not yet convinced.

Developmental programs and interventions of MNP and other actors such as SAGE and AEECL play an important role in this process. However, their activities need to be well coordinated in order to prevent frustration. In 2007, WCS and AEECL initiated many activities in Sahamalaza that subsequently had to be terminated. As a consequence, the local people became disillusioned and returned to their old habits. In Mananara, locals got used to the developmental support that started during the Integrated Conservation and Development Project (ICDP) phase and continued in the following years when the project had adequate funding. As finances have recently become insecure, developmental activities were reduced, yet locals still demand greater support. The outcome remains to be seen.

Furthermore, it is important that user associations gain management rights from the state in order to legitimize the local property right regime because formal state recognition validates user rights. State recognition increases tenure security and creates greater incentives for users to participate in management and to invest in the resource

(Meinzen-Dick et al. 2004). The zonation in biosphere reserves allows for clear allocation of terrains, in accordance with the designated buffer zone and *Zone d'Utilisation Contrôlée* (ZUC). A positive example of this is the implementation in the Mananara-Nord BR in the form of a green belt.

In Sahamalaza, however, the absence of state recognition of GELOSE is one of the major problems of the CLB and inhibits the effective application of the *dina*. Therefore, the acknowledgment of their rights creates the basis for a more egalitarian relationship among all stakeholders and can contribute to better service relationships in natural resource management. Because there is no formal land register, the traditional way of land reclamation by *tavy* is still common practice, which in turn can lead to major socio-economic problems. An example is the tensions that arose when the protected areas were established because many farmers were forced to leave farmland of which they felt themselves to be the 'real' owners. It is necessary to go beyond the dualistic opposition between 'formal state law' and 'local customary law' to reconcile contradictions between the informal rules-in-use and the formal rules.

CONCLUSION

This study affirms the importance of the management transfer as a tool to transfer property rights and thereby enhance tenure security and sense of responsibilities for collective action. It demonstrates the potential of local customs and traditional social systems to influence the success of collective resource management.

We showed that the institutions investigated are partly incompatible and even conflictive. However, considering these social and cultural relations as a resource that can facilitate access to and management of other (inter alia natural) resources sheds light on their instrumental value. Meaningful integration of the different customs and informal 'rules-in-use' as well as their harmonzation with formal state regulation is essential for collective resource management. All forms of social capital discussed above, can influence collective action in both positive and negative ways. Increasing local responsibility and political legitimacy is vital in this respect. Understanding and considering traditional administrative hierarchies along with power relations help to prevent conflicts and reconcile local sensitivities.

When contrasting the Mananara-Nord and Sahamalaza Biosphere Reserves, the types of social capital seem to have different levels of importance for the implementation of GELOSE / GCF. With respect to the management transfer, the need for a long-term vision and continued investment is obvious. Empowering and stimulating engagement in conservation requires a change of attitudes and behavior – which takes time. In Mananara, the COBA have recently been evaluated successfully, and their contract extended for another ten years. This opens up long-term incentives and builds on the confidence in local people's work.

Especially the context of biosphere reserves, where many different actors convene, dialogue is of particular importance. The two Malagasy biosphere reserves could benefit from a mutual exchange; so far, communication between them is virtually non-existent. A dense network of relationships should go beyond local structures and become common place.

ACKNOWLEDGEMENTS

We thank Madagascar National Parks for collaborating with us and providing facilities and information, in Mananara-Nord especially: Willy Mora (Director), Thierry and Narcisse (*Chefs secteur*), and in Sahamalaza: Isaia Raymond (Director), Urbain and Tsara (*Chefs secteur*). We are grateful to the Robert Bosch Stiftung for funding the GoBi research project within which this study was conducted and the Tierschutz-Stiftung Wolfgang Bösche for additional funding. We also thank Nele Leiner, Cristina de la Vega-Leinert, Mike McLoone, Vadim Michailov, all interviewees and last but not least the three anonymous reviewers for their very valuable comments.

REFERENCES

Agrawal, A. and Gibson, C. C. 1999. Enchantment and disenchantment: The role of community in natural resource conservation. World Development 27: 629-649. (doi:10.1016/S0305-750X(98)00161-2)

Association Nationale pour la Gestion des Aires Protégées (ANGAP) 2008. Rapport des Activités Techniques du Deuxième Trimestre 2008. Unpubl. Report, ANGAP PN Sahamalaza, Direction Inter-Régionale Mahajanga, Maromandia.

ANGAP and Ministère de l'Environnement, des Forêts, et du Tourisme (MEEFT) 2008. Plan Sauvegarde Sociale et Environnementale du Parc National Sahamalaza – Iles Radama. Unpubl. Report, ANGAP PN Sahamalaza, Maromandia.

ANGAP, Union Européenne (UE) & Intercoopération (IC) 2005. Plan de Gestion de la Conservation – Parc National Mananara-Nord, ANGAP. Unpubl. Report, ANGAP RB Mananara-Nord, Union Européenne and Intercoopération Suisse, Mananara-Nord.

ANGAP 2003. Réserve de Biosphère Mananara-Nord. Plan de Gestion de Développement. Unpubl. Report, ANGAP RB Mananara-Nord, Mananara-Nord.

Antona, M., Motte Biénabe, E., Salles, J.-M., Péchard, G., Aubert, S. and Ratsimbarison, R. 2004. Rights transfers in Madagascar biodiversity policies: Achievements and significance. Environment and Development Economics 9: 825-847. (doi:10.1017/S1355770X04001640)

Ascher, W. 1995. Communities and Sustainable Forestry in Developing Countries (Self-Governing Communities). Institute for Contemporary Studies Press, San Francisco.

Association des Planteurs de Mananara, Intercoopération Madagascar, Parc National Mananara – ANGAP & Fondation Slowfood pour la Biodiversité 2008. Presidia Vanille de Mananara – Rapport d'avancement 2007. Unpubl. report, Mananara.

Belvaux, E. & Rabearisoa, A. 2006. Valorisation économique, exploitation raisonnée, utilisation durable et transfert de gestion des ressources naturelles aux communautés de base : quelle compatibilité ? Communication au colloque « Gestion concertée des ressources naturelles et de l'environnement – du local au mondial » Université de Versaille St Quentin en Yvelines, France, 26-28 juin.

Bourdieu, P. 1986. The forms of capital. In: Handbook of Theory and Research for the Sociology of Education. J. Richardson (ed.), pp 241-258. Greenwood, New York.

Coleman, J. S. 1988. Social capital in the creation of human capital. The American Journal of Sociology 94: 95-120.

Commission SAPM 2006. Système des Aires Protégées de Madagascar – Orientations générales sur les catégories et les types de gouvernance des aires protégées. Ministère de l'Environnement, des Eaux et Forêts, Direction Générale des Eaux et Forêts, Antananarivo.

Conservation International, Ministère de l'Environnement, des Eaux et Forêts and United States Agency for International Development (USAID) 2007. Change in natural forest cover Madagascar 1990-2000-2005. Conservation International, Washington D. C.

Dahal, G. R. and Adhikari, K. P. 2008. Bridging, linking, and bonding social capital in collective action. Working paper No. 79, International Food Policy Research Institute, Washington.

Dahl, Ø. 1993. Malagasy Meanings – An Interpretive Approach to Intercultural Communication in Madagascar. Misjonshøgskolens forlag, Stavanger, Norway.

Denzin, N. K. and Lincoln, Y. S. 2003. Introduction – the discipline and practice of qualitative research. In: The Landscape of Qualitative Research – Theories and Issues. N. K. Denzin and Y. S. Linclon (eds.), pp 1-32. Sage Publications, Thousand Oaks, California.

Dudley, N. 2008. Guidelines for Applying Protected Area Management Categories. IUCN Gland, Switzerland.

Erdmann, T. K. 2003. The dilemma of reducing shifting cultivation. In: The Natural History of Madagascar. S. M. Goodman and J. P. Benstead (eds.), pp 134-139. The University of Chicago Press, Chicago.

Flick, U. 2008. Geschichte und Theorie der Triangulation. In: Triangulation – eine Einführung. U. Flick (ed.), pp 11-26. VS Verlag für Sozialwissenschaften, Wiesbaden.

Flick, U. 2007. Qualitative Sozialforschung – eine Einführung. Rowohlts Enzyklopädie, Hamburg.

Fritz-Vietta, N. V. M. and Stoll-Kleemann, S. 2008. How to foster organisational capacity for integrated biosphere reserve management: The Biosphere Reserve Mananara-Nord, Madagascar. GAIA 17: 169-176.

Fritz-Vietta, N. V. M., Röttger, C. and Stoll-Kleemann, S. 2008. Enhancing management effectiveness in the Biosphere Reserve Mananara-Nord. GoBi-Discussion Paper No. 2, Ernst-Moritz-Arndt Universität Greifswald, Greifswald.

Gezon, L. 1997. Institutional structure and the effectiveness of integrated conservation and development projects: Case study from Madagascar. Human Organization, 56: 462-470.

Glaser, B. G. and Strauss, A. 1967. Discovery of Grounded Theory – Strategies for Qualitative Research. Aldine Publishing Company, Chicago.

Gesellschaft für Technische Zusammenarbeit (GTZ) & Ministère de l'Environnement, des Forêts et du Tourisme (MEEFT) 2008. Etat des lieux sur les transferts de gestion. Unpubl. report, programme Gestion Durable des Ressources Naturelles, Antananarivo.

High, C., Pelling, M. and Nemes, G. 2005. Understanding informal institutions: Networks and communities in rural development. Paper presented at the Transition in Agriculture, Agricultural Economics in Transition II, Hungary.

Hockley, N. J. and Andriamarovololona, M. M. 2007. The economics of community forest management in Madagascar: Is there a free lunch? USAID, Antananarivo.

Jacoby, H. and Minten, B. 2005. Is land titling in sub-saharan Africa cost-effective? Evidence from Madagascar. The World Bank and Cornell University, Cornell.

James, A. N., Green, M. J. B. and Paine, J. R. 1999. A Global Review of Protected Area Budgets and Staffing, World Conservation Monitoring Center Biodiversity Series No. 10, Cambridge.

Jones, J. P. G., Andriamarovololona, M. M. and Hockley, N. 2008. The importance of taboos and social norms to conservation in Madagascar. Conservation Biology 22: 976-986. (doi:10.1111/j.1523-1739.2008.00970.x)

Kistler, P. and Spack, S. 2003. Comparing agricultural systems in two areas of Madagascar. In: The Natural History of Madagascar. S. M. Goodman and J. P. Benstead (eds.), pp 123-134. The University of Chicago Press, Chicago.

Kull, C. A. 2002. Empowering pyromaniacs in Madagascar: Ideology and legitimacy in community-based natural resource management. Development and Change 33: 57-78. (doi : 10.1111/1467-7660.00240)

Meinzen-Dick, R. S., Pradhan, R. and Di Gregorio, M. 2004. Understanding property rights. In: Collective Action and Property Rights for Sustainable Development. R. S. Meinzen-Dick and M. Di Gregorio (eds.), pp 7-8. The International Food Policy Research Institute (IFPRI), Washington.

North, D. C. 1994. Institutional change: A framework of analysis. EconWPA, 9412001: 1-23.

Paavola, J. and Adger, W. N. 2002. New institutional economics and the environment: Conceptual foundations and policy implications. Working Paper, University of East Anglia, Norwich.

Poteete, A. and Ostrom, E. 2002. An Institutional Approach to Study Forest Resources. Working Paper 01-8, International Forestry Resources and Institutions (IFRI) Research Program Indiana University, Bloomington.

Pretty, J. 2003. Social capital and the collective management of resources. Science 302: 1912-1914. (doi:10.1126/science.1090847)

Punch, K. F. 2005. Introduction to Social Research – Quantitative and Qualitative Approaches. SAGE Publications Ltd., Wiltshire.

Putnam, R. D. 2000. Bowling Alone: The Collapse and Revival of American Community. Simon and Schuster, New York.

Putnam, R. D., Leonardi, R. and Nanetti, R. Y. 1994. Making Democracy Work: Civic Traditions in Modern Italy. Princeton University Press, New York.

Raik, D. 2007. Forest management in Madagascar: An historical overview. Madagascar Conservation & Development 2: 5-10.

Raik, D. B. and Decker, D. J. 2007. A multisector framework for assessing community-based forest management: Lessons from Madagascar. Ecology and Society 12: 14.

Rakotoson, L. R. and Tanner, K. 2006. Community-based governance of coastal zone and marine resources in Madagascar. Ocean and Coastal Management 49: 855-872.

Raondry, N., Klein, M. & Rakotonirina, V. S. 1995. La Réserve de Biosphère de Mananara-Nord 1987-1994 : bilan et perspectives. Working paper No. 6, UNESCO, Paris.

Resolve Conseil, PCP & IRD 2005. Evaluation et perspectives des transferts de gestion des ressources naturelles dans le cadre du Programme Environnemental 3. Synthesis report, Resolve Conseil, Antananarivo.

Salafsky, N. and Wollenberg, E. 2000. Linking livelihoods and conservation: A conceptual framework and scale for assessing the integration of human needs and biodiversity. World Development 28: 1431-1438.

SAVAIVO 2003. Etude d'Impact Environnemental d'un projet APMC dans le Site « Sahamalaza – Iles Radama ». Unpubl. report, Bureau d'études SAVAIVO, Antananarivo.

Sörensen, L. 2005. Waldmanagement auf vertraglicher Basis durch lokale Gemeinschaften – eine Studie an zwei Fallbeispielen aus Madagaskar. Unpubl. diploma thesis, Ernst-Moritz-Arndt Universität Greifswald, Greifswald.

Stoll-Kleemann, S. and Welp, M. 2006. Stakeholder Dialogues in Natural Resources Management: Theory and Practice. Springer, Berlin, Heidelberg, New York.

Tengö, M., Johansson, K., Rakotondrasoa, F., Lundberg, J., Andriamaherilala, J.-A., Rakotoarisoa, J.-A. and Elmqvist, T. 2007. Taboos and forest governance: Informal protection of hot spot dry forest in southern Madagascar. AMBIO: A Journal of the Human Environment 36: 683-691.

UNESCO. 1996. Biosphere reserves: The Seville strategy and the statutory framework of the world network. UNESCO, Paris.

UNESCO 2000. Solving the puzzle: The ecosystem approach and biosphere reserves. UNESCO, Paris.

UNESCO, ANGAP & DEC 2001. Parc National Mananara-Nord: Plan d'Aménagement et de Gestion 2002-2006. Unpublished management plan, ANGAP, Mananara-Nord.

UNESCO MAB Secretariat 2009. Biosphere reserves – world network, réseau mondial, red mundial. UNESCO, Paris.

Wainwright, C. and Wehrmeyer, W. 1998. Success in integrating conservation and development? A study from Zambia. World Development 26: 933-944. (doi:10.1016/S0305-750X(98)00027-8)

Wells, M., Brandon, K. and Hannah, L. 1992. People and Parks: Linking Protected Area Management with Local Communities. The International Bank for Reconstruction and Development/The World Bank, Washington, D.C.

Williamson, O. E. 2000. The new institutional economics: Taking stock, looking ahead. Journal of Economic Literature 38: 595-613.

World Bank, USAID, Coopération Suisse, UNESCO, UNDP and WWF 1988. National Environmental Action Plan – Document de synthèse générale et propositions d'orientations. Report E 0021, Government of Madagascar, Antananarivo.

The Madagascar rosewood massacre

Derek Schuurman and Porter P. Lowry II[1]

Correspondence:
Derek Schuurman
E-mail: derekschuurman7@yahoo.co.uk

ABSTRACT

Valuable timber has been exploited from Madagascar's rainforests for many decades, and Malagasy rosewood and *palissandre* (*Dalbergia* spp.) are among the most sought after hardwoods in the world. Large quantities have been harvested and exported at an increasing rate over the last decade, almost entirely from illegal logging in protected areas, in particular Masoala and Marojejy National Parks, which comprise part of the newly-established Atsinanana UNESCO World Heritage Site in the SAVA (Sambava - Antalaha - Vohémar - Andapa) region of northeast Madagascar. We present information obtained from sources in the region that documents an unprecedented, highly organized expansion in the illegal timber trade operating openly in the wake of the country's current political turmoil, with more than 625 containers of rosewood worth an estimated US $ 130 million leaving just from the port of Vohémar (Iharana) since early 2009 to cater for the demand of the international market. Members of local communities around Masoala and Marojejy derive very little benefit from timber harvesting, which severely compromises the integrity of the protected areas and their ecosystems, while nearly all the profits go to those who run the illegal operations. Income from ecotourism and other potential benefits is limited at Masoala and Marojejy by the region's climate, relative inaccessibility and poor infrastructure, making it nearly impossible for locals to resist short-term gains from forest exploitation. Insufficient in numbers and lacking authority, park staff are unable to effect any control over logging activity within protected areas. The current scramble for resources in Madagascar's parks and reserves challenges the viability of the previous government's plans to protect 10% of the country and calls into question the conservation commitment of the current regime.

RÉSUMÉ

Les bois précieux de Madagascar ont fait l'objet d'une exploitation forestière pendant de nombreuses années en portant notamment sur l'ébène (*Diospyros* spp.), le bois de rose et le palissandre (*Dalbergia* spp.) qui font partie des essences les plus prisées au monde. D'importants volumes de bois précieux ont ainsi été exportés avec une augmentation exponentielle au cours de la dernière décennie passant de quelques centaines de tonnes par mois en 1998 à plus de 30,000 tonnes entre juillet 2000 et juin 2001. Ces bois précieux ont presque tous été obtenus d'une exploitation illicite en provenant des aires protégées et plus particulièrement des Parcs Nationaux de Marojejy et de Masoala dans la région SAVA (Sambava-Antalaha - Vohémar- Andapa) au nord-est de Madagascar. Ces parcs ont été récemment reconnus au titre de patrimoine mondial de l'UNESCO dans la nouvelle région des forêts humides de l'Atsinanana. Nous présentons des informations obtenues de sources régionales qui montrent qu'une organisation d'un trafic sans précédent de l'exploitation illégale dans les aires protégées s'est mise en place au moment de la crise politique qui a commencé dans le pays au début de 2009 avec l'exportation de 625 conteneurs d'une valeur estimée de US $ 130 millions du seul port de Vohémar (Iharana), pour couvrir la demande du marché international. Les membres des communautés villageoises limitrophes des parcs de Masoala et de Marojejy ont peu profité de la manne que représente l'exportation de ce bois précieux qui compromet par ailleurs l'intégrité des zones protégées et leurs écosystèmes alors que la quasi-totalité des gains va à ceux qui organisent le trafic. Les revenus de l'écotourisme et d'autres activités sont limités aussi bien dans les parcs de Masoala que du Marojejy par le climat de la région, l'inaccessibilité relative et des infrastructures modestes qui font qu'il est difficile aux gens de la région de résister aux gains à court terme de l'exploitation forestière car elle représente leur seule bouée de sauvetage en cas de crise, qu'il s'agisse d'un cyclone saisonnier ou d'une crise politique comme celle de 2009, d'autant que les agents des parcs n'ont pas les moyens de s'y opposer et ne sont pas assez nombreux. La course actuelle aux ressources des parcs et réserves de Madagascar compromet la légitimité et la viabilité du plan de l'ancien gouvernement de protéger 10% du pays et remet en cause l'engagement pour la protection de la nature du régime actuel.

KEYWORDS: Illegal logging, rosewood, ebony, *Dalbergia, Diospyros.*

MOTS CLEF : exploitation forestière illégale, bois de rose, palissandre, ébène, *Dalbergia*, *Diospyros.*

[1] Africa and Madagascar Department, Missouri Botanical Garden, P.O. Box 299, St. Louis, Missouri 63166-0299, USA, E-mail: Pete.Lowry@mobot.org; Département Systématique et Évolution, Muséum Nationale d'Histoire Naturelle, Case Postale 39, 57 rue Cuvier, 75231 Paris, CEDEX 05, France

INTRODUCTION

Madagascar's forests have long been under intense and rapidly increasing pressure from various sectors of society, including members of impoverished communities living around protected areas and well organized criminal networks with extensive international links. Over the last few years, this pressure has reached unprecedented levels and is having an immense, unsustainable and in many cases irreversible impact on some of the country's most vulnerable ecosystems.

Madagascar's botanical diversity is exceptionally high, with an estimated 13-14,000 species of vascular plants, a majority of which occur in forest habitats, and more than 90% of which occur nowhere else on earth (Phillipson et al. 2006). Some of the island's tree species have a high commercial value, in particular the rosewoods and *palissandres* (members of the genus *Dalbergia* L. f., Fabaceae) and ebonies (*Diospyros* L., Ebenaceae) (Wilmé et al. 2009). *Dalbergia* includes 48 currently recognized species in Madagascar (Bosser and Rabevohitra 1996, 2005, Du Puy et al. 2002), and *Diospyros* has ca. 85 recognised Malagasy species, with nearly twice as many still unnamed (Schatz 2001, Schatz in litt.). Despite recent taxonomic work on these important groups, very little is known about their biology and ecology, and the details of their classification remain poorly understood and largely inaccessible to those working in the forestry sector. Moreover, the efforts of scientists and conservationists to educate local people about the value of living trees and intact forests have been hampered, while in contrast, local community members are acutely aware of the commercial value of these tree species in the form of cut wood. Vernacular names provide a clue to this division: For example 'rosewood' and *palissandre* are clearly distinguishable by those involved in any aspect of forestry or in the timber trade (Schatz 2001, Stasse 2002) despite representing members of a single well-delimited and widely recognised genus. The conservation significance of valuable hardwoods has received scant investigative attention in Madagascar, with rare exceptions such as those focussed on the western coastal region(Ganzhorn and Sorg 1996).

Logging in Madagascar has been regularly documented over the decades but legislation pertaining to the organised export of precious timber has never been reported on in depth. Nor has it received sufficient interest from international conservation and development agencies in the context of measuring the current level of timber harvesting and the volume of wood exported, and, to assess whether these levels are sustainable.

According to André Peyrieras (in litt.), when precious timber was exploited during the colonial period (1896-1960), some of the most sought-after *palissandre* was exported from Madagascar to Le Havre, France. From there, it was sent on to Brazil and subsequently returned to France under the label '*Palissandre de Rio*' (a trade name for *Dalbergia nigra*, incidentally the only species in the genus currently protected under CITES). Peyrieras also noted that the particularly alluring wood of certain *Dalbergia* species found on Montagne d'Ambre in northern Madagascar was sent to France, where it was made into furniture marketed as 'False Rosewood'. Significantly Peyrieras pointed out that rosewood originating from the areas around Sambava, Andapa and Antalaha was regarded as being of poor quality because it was difficult to work with and was therefore less valuable. He indicated that the highest quality rosewood came from the southern half of the Masoala Peninsula, where precious wood was exploited extensively in the 1960s in accessible places below 400-500m in elevation.

There has long been an understanding among local authorities that legislation relating to these precious sources of timber is a complex matter, and the status of its export has oscillated between outright bans, the first of which dates back to 1975 (Ballet and Rahaga 2009), followed by periodic exceptions. In 2000, the Government of Madagascar adopted a decree to stop the export of precious timber from October 2000 for three years (decree N. 11832 / 2000). Existing permits were still considered valid, but with certain conditions attached, such as the prohibiting of exporting any unprocessed wood. The quantity of timber exported since, however, is said to be substantial, although statistics appear to have remained in the possession of the Ministry of Water and Forests. Findings from in-depth studies conducted on the subject remain in grey literature, for example the unpublished report by Stasse (2002) detailing the investigation she conducted.

The 2000 decree allowed for the exporting of 10,000 tons of rosewood which was considered to be 'felled by cyclones'. The decree also permitted exporting of rosewood, which had been harvested before cyclones – a quantity which local authorities in the SAVA region put at approximately 25,000 tons. This rosewood had to be moved to Toamasina by 30 June 2001 and exported by 30 September 2001, but according to research by Stasse in 2002, only some 7,900 of the 10,000 tons of timber had actually reached Toamasina in time.

In this paper we aim to provide an overview of the nature, and where appropriate the history of the predicament facing some of Madagascar's protected areas, which are under extreme pressure from illegal timber exploitation that is thriving in the chaos of Madagascar's current political situation.

METHODS

Information has primarily been gathered in the SAVA region in north-eastern Madagascar, where precious timber has been sourced for decades from rainforests, including a network of protected areas designated as the Atsinanana UNESCO World Heritage Site in 2007 (Figure 1). For this article, reliable, well-placed sources collected photographs of illegal exploitation and transportation of harvested trees and of shipping documents detailing a burgeoning trade in illegally-sourced timber, which are also presented in a poster prepared for the World Forestry Congress held in Buenos Aires, Argentina, 18-23 October 2009 (Wilmé et al. 2009, see Supplementary Material). We also used sources from the grey literature (in particular Stasse 2002, cited in Ormsby and Kaplin 2005) and recently released reports (e.g., Ballet and Rahaga 2009).

RESULTS AND DISCUSSION

The data we have compiled for the present study on the export of precious timber includes some astonishing revelations:

- The number of logs of precious timber exported monthly from the port of Toamasina increased from 332 in 1998 to 4,108 in 2000.
- Between 2002 and 2009 logging of rosewood was strictly forbidden in any protected areas. However, according to unpublished reports by WCS, logging was happening in Masoala National Park and also in Marojejy (Patel 2007).

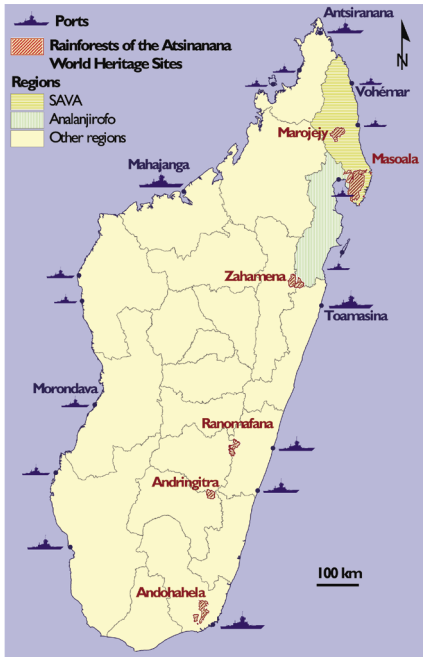


FIGURE 1. The six National Parks included in Atsinanana UNESCO World Heritage Sites, the SAVA and Analanjirofo regions in Northeastern Madagascar, and the ports along Madagascar coasts.

- Research published by Kozak and Canby (2007) reveals that China is purchasing vast quantities of unprocessed timber from various countries. This is also alluded to in Goldstein et al. (2006).
- If we consider evidence such as numerous shipping documents detailing rosewood shipments from Vohémar in particular during 2009 it is clear that the bulk of the illegally-sourced rosewood was shipped to several Chinese ports. This assertion is supported by Stasse (2002) and Razafindramiadana (2009). The rosewood stock extracted from the SAVA region and exported from Vohémar can be estimated at 17,194 tons of wood between July 2000 and June 2001 with an approximate number of trees felled at ca. 43,500. These respective numbers have been estimated for the Analanjirofo region with exporting from Toamasina of 14,284 tons of wood or 36,500 trees for the same period (Table 1).
- The timber exported from Toamasina in 2001 originated mainly from the Masoala Peninsula, including Masoala National Park, but also from Marojejy National Park (Stasse 2002).
- A total number of 571 containers of rosewood, worth an estimated US $ 120 million, was exported between late January and the end of April 2009 (Wilmé et al. 2009).
- Another shipment of 55 containers (containing ca. US $ 11.5 million worth of wood) was assembled and exported to China on 31 October 2009 (Table 2, Maka 2009).

Illegal logging of rosewood in Masoala National Park is widespread and involves individuals from communities surrounding much of the park, as reported by Ormsby and Kaplin (2005). Interviews conducted for their study indicated that people have benefited from a variety of illegal activities, particularly lemur hunting and harvesting of precious timber. Ormsby and Kaplin (2005) also revealed that emigrants come to Masoala from other areas to log rosewood as they have no other means of earning an income. Pressure on natural resources in Madagascar's parks and reserves – each of which has its own complexities regarding management issues – comes from various groups, ranging from impoverished subsistence farmers to cunningly organised international timber dealers. Ormsby and Kaplin (2005) confirmed that precious timber is harvested from inside Masoala National Park and that the bulk of the wood is exported to international markets. They also allude to the challenging nature of any attempts to enforce existing laws, pointing out that park agents lack the authority to arrest people caught logging timber in protected areas. The terrain in both Masoala and Marojejy National Parks is exceptionally rugged, and the ratio of park rangers to loggers is hopelessly small – approximately one park employee per 100 km² (Schuurman 2009).

One log of rosewood is ca. 196 kg (Stasse 2002). The logs are then transported by people from inside of the forests and then floated on rafts or carried on dugout canoes. They are then transported in trucks to ports where they are packed into containers (Débois 2009). The loaded containers in Vohémar weigh ca. 20 tons (an empty container is 2.2 tons). Larger

TABLE 1. Exportation of rosewood from Antalaha and Toamasina between July 2000 and June 2001 estimated from numbers given in Stasse (2002).

	Port of Vohémar		Port of Toamasina		Totals Northeast	
Month	Number of logs	Weight (tons)	Number of logs	Weight (tons)	Number of logs	Weight (tons)
VII 2000	7,700	1,509	1,782	349	9,482	1,859
VIII 2000	8,669	1,699	9,732	1,908	18,401	3,607
IX 2000	15,091	2,958	4,168	817	19,259	3,775
X 2000	16,184	3,172	11,508	2,256	27,692	5,428
XI 2000	13,038	2,555	8,055	1,579	21,093	4,134
XII 2000	0		0		0	
I 2001	0		8,877	1,740	8,877	1,740
II 2001	1,931	379	3,914	767	5,845	1,146
III 2001	3,547	695	9,608	1,883	13,155	2,578
IV 2001	7,350	1,441	425	83	7,775	1,524
V 2001	8,068	1,581	6,905	1,353	14,973	2,935
VI 2001	6,147	1,205	7,903	1549	14,050	2,754
TOTALS	87,725	17,194	72,877	14,284	160,602	31,478
Estimated number of trees	ca. 43,500		ca. 36,500		ca. 80,000	

TABLE 2. Values from the 55 containers of 'legalized' illegally-logged rosewood exported from Vohémar (Iharana) on 31st October 2009. The numbers have been obtained from a Cargo Manifest belonging to UAFL Mauritius; the weight declared may be underestimated as it is common practice, reported by Stasse (2002) who gives a mean weight of 196 kg per log.

Shippers	Declared weight (tons)	Number of logs	Estimated value	Destination
GUERRA William	180	1386	$2,000,000	Beijing Yintuo, Hong Kong
BEMATANA Martin	180	1080	$2,000,000	Beijing Yintuo, Hong Kong
NDAHINY Gregoire	270	2181	$3,000,000	Beijing Yintuo, Hong Kong
NDAHINY Gregoire	90	705	$1,000,000	China Meheco Traditional Medecines & Health Products,Beijing
CHAN HOY LANE	54	446	$600,000	Shanghai Tong Sheng, Shanghai
BODY Thierry	215	1469	$2,400,000	Zhyangjiagang Free Trade, Jianghsu
TOTALS	989	7267	$11,000,000	

cranes in Toamasina port allow for the use of containers twice as large and able to accommodate double the weight of those used in Vohémar port. In most cases, a mature tree is divided into two logs. Using the above information it can be deduced that 17,194 tons of timber are made up of about 85,970 logs -in other words, an estimated 42,985 trees were sourced from the area's rainforests and shifted out of the country virtually unnoticed (until recently) by the international conservation community working in the protected areas of the Atsinanana World Heritage Site. The apparent sole exception was an article published by a research anthropologist (Patel 2007).

Local communities derive very little benefit from logging precious timber, despite the fact that it is an extremely demanding and labour-intensive activity (Stasse 2002, Patel 2007). People living around Masoala and Marojejy National Parks who are inclined to favour protection of these areas find themselves in a complicated predicament. The northeast has a per-humid seasonal climate, a largely rugged and mountainous geography that makes travel and access difficult, and minimal infrastructure, all of which limit tourism, long promoted as a potentially important alternative source of income. Ormsby and Mannle (2006) indicate that a maximum of 2,000 visitors come to Masoala annually, 78 % of whom only go as far as the easily accessible Nosy Mangabe island reserve, where wildlife viewing is virtually effortless. Marojejy National Park has the capacity to cater for far fewer tourists (Bradt 2007).

Almost annually, the SAVA region is struck by violent tropical storms. When Cylone Hudah left 50,000 people homeless in April 2000 (Birkinshaw 2007), the inevitable result was a marked increase in tavy (slash and burn agriculture), hunting of wildlife for food, and more intensive harvesting of precious hardwoods (Ormsby and Kaplin 2005). Patel (2007) cites additional reasons for increased illegal logging in the SAVA region, including the devastating decline in the price offered for the main cash crop, vanilla, which fell from US $ 230 to US $ 25 per kg between 2003 and 2005 (Débois 2009). Its value is currently less than US $ 27 per kg (Baillard 2009)

If the government or aid agencies were to allocate emergency funds to assist the people affected by cyclones this would probably only alleviate short-term problems and would therefore not be sufficient to create an opportunity for people who have just lost everything to re-establish themselves. Local residents are thus forced to draw even more heavily on natural resources within protected areas. This insidious cycle is likely to intensify as the projected impacts of global and regional climate change become increasingly apparent, and in particular as storm frequency and intensity increase (Hannah et al. 2008). These natural events are further compounded during times of political turmoil such as in 2002 and 2009, casting doubt over whether many of the conservation efforts in Madagascar – a donor-dependent country widely regarded as one of the world's foremost conservation priorities – have a chance of succeeding in the long-term (Rabesala Horning 2008).

Illegal selective logging for high-value timber species is by no means limited to Masoala and Marojejy National Parks. Similar, albeit thus far perhaps less intense, extraction of valuable trees from protected areas takes place throughout the country and timber is shipped out of most of the island's ports (Figure 1). Given that logging of precious timber has been problematic for many decades in Madagascar, one could question whether political turmoil is the main spark that sets off pillaging of valuable timber from protected areas, or alternatively whether the drive to exploit valuable and sought-after resources such as rosewood on legally public land might contribute to political turmoil, for instance when some members of the higher echelons of Malagasy society are excluded from benefiting from the lucrative trade in natural resources.

CONCLUSIONS

We conclude that the 11932/2000 decree resulted in continuing illegal logging in Madagascar's protected areas, through the events of 2002 and up to the present (November 2009). A paucity of published information between 2000 and 2008 has not helped matters, though it is clear from the grey literature (e.g., Stasse 2002) that Madagascar's forests have suffered significantly during periods of political turmoil. The absence of proper studies – and therefore information necessary to have the appropriate legislation formulated and measures implemented – have allowed for this to happen again in 2009.

Illegal logging and export of rosewood taken from protected areas almost exclusively benefits the small number of individuals who organize and manage the trade and a few strategically placed persons in government. Regimes, it would seem, have a tendency to allow for 'exceptions' (the decrees) when it comes to legislation concerning export of precious timber, particularly during periods of political instability. Impoverished

local people – those who suffer most due to weak governance and also sanctions – are virtually forced into a situation where they have to seek employment in the illegal logging industry.

The accelerating run now being made for Madagascar's precious wood is driven by a continually growing demand in the international market, particularly in China (Laurance 2008). Under President Marc Ravalomanana, Madagascar's previous government set a goal of legally protecting 10 % of the country's area. One would have hoped and expected that more stringent measures would be in place to conserve what remains of Madagascar's dwindling forests. Even following a regime change, no government should permit – let alone condone or encourage – illegal logging in its parks and reserves. Yet this has happened for decades in Madagascar under successive governments, although perhaps never before at such a frenzied pace as we are witnessing today (Lough 2009, Wilmé et al. 2009).

What can be done to alleviate the current situation? We proposed that (i) The identities of all exporters, of all members of the 'timber mafia', of buyers and of shipping companies should be publically revealed; (ii) While it may be a time-consuming process, perhaps all species of *Dalbergia* should receive protection under CITES. Detailed taxonomical work needs to be completed by botanists and the information shared with forestry specialists, so published knowledge on populations of 'target' species is accessible and can be used for the formulation of policies geared to protect what remains of Madagascar's forests; (iii) There is a need for an increase in the number of park staff as well as in the level of authority granted to staff responsible for patrolling parks, so people caught in the act of illegal logging within protected areas can be dealt with appropriately.

ACKNOWLEDGMENTS

We would like to thank our sources, most of whom have placed their lives at risk gathering information presented in this paper. Three anonymous reviewers are acknowledged for their comments and feedback.

REFERENCES

Baillard, D. 2009. Commerce. La vanille va mal. Tribune. Édition du 23 septembre 2009. <http://www.madagascar-tribune.com/La-vanille-va-mal,12774.html> accessed 31 October 2009.

Ballet, J. & Rahaga, N. 2009. Impact Économique des Arrêtés autorisant les Exportations de Bois Précieux à Madagascar. Unpublished report to PGM-E/GTZ.

Birkinshaw, C. and Randrianjanahary, M. 2007. The effects of cyclone Hudah on the forest of Masoala Peninsula, Madagascar. Madagascar Conservation & Development 2: 17-20.

Bosser, J. & Rabevohitra, R. 1996. Taxa et noms nouveaux dans le genre *Dalbergia* (Papilionaceae) à Madagascar et aux Comores. Bulletin du Museum national d'Histoire naturelle, 4e sér., 18: 171-212.

Bosser, J. & Rabevohitra, R. 2005. Espèces nouvelles dans le genre *Dalbergia* (Fabaceae, Papilionoideae) à Madagascar. Adansonia, Sér. 3, 27, 2: 209-216.

Bradt, H. 2007. Madagascar. Bradt Travel Guide, Chalfont St. Peter, U.K.

Débois, R. 2009. La fièvre de l'or rouge saigne la forêt malgache. Univers Maoré 13: 8-15.

Du Puy, D. J., Labat, J.-N., Rabevohitra, R., Villiers, J.-F., Bosser, J. and Moat, J. 2002. The Leguminosae of Madagascar. Royal Botanic Gardens, Kew, U.K..

Ganzhorn, J. U. and Sorg, J.-P. (Eds.) 1996. Ecology and Economy of a Tropical Dry Forest in Madagascar. Primate Report Special Issue 46, 1: 1-382.

Goldstein, A., Pinaud, N., Reisen, H. and Chen, X. 2006. The rise of China and India: What's in it for Africa? OECD Publishing.

Hannah, L., Dave, R., Lowry II, P. P., Andrianarisata, M., Cameron, A., Hijmans, R., MacKinnon, J., Randrianasolo, H. H., Andriambololonera, S., Razafimpahanana, A., Randriamahazo, H., Randrianarisoa, J., Razafinjatovo, P., Raxworthy, C., Schatz, G. E., Tadross, M. and Wilmé, L. 2008. Climate change adaptation for conservation in Madagascar. Biology Letters 4: 590-594. (doi:10.1098/rsbl.2008.0270)

Kozak, R. and Canby, K. 2007. Why China prefers logs. Explaining the prevalence of unprocessed wood in China's timber imports. Forest Trends 9: 1-5.

Laurance, W. F. 2008. The need to cut China's illegal timber imports. Science 319: 1184-1185. (doi:10.1126/science.319.5867.1184b)

Maka, A. Exploitation illicite de bois de rose. Parc national de Masoala ravagé. La Vérité 19 août 2009. < http://www.laverite.mg/actualites-a-madagascar/exploitation-illicite-de-bois-de-rose-parc-national-de-masoala-ravage.html> accessed 20 August 2009.

Lough, R. 2009. Madagascar accused of profiting from illegal timber. Reuters 3 October 2009.

Ormsby, A. and Kaplin, B. A. 2005. A framework for understanding community resident perceptions of Masoala National Park, Madagascar. Environmental Conservation 32, 2: 156-164. (doi:10.1017/S0376892905002146)

Ormsby, A. and Mannle, K. 2006. Ecotourism benefits and the role of local guides at Masoala National Park, Madagascar. Journal of Sustainable Tourism 14, 3: 271-287. (doi:10.1080/09669580608669059)

Patel, E. R. 2007. Logging of rare rosewood and palisandre (*Dalbergia* spp.) within Marojejy National Park, Madagascar. Madagascar Conservation & Development 2, 1: 11-16.

Phillipson, P. B., Schatz, G. E., Lowry II, P. P. and Labat, J.-N. 2006. A catalogue of the vascular plants of Madagascar. In: Taxonomy and Ecology of African Plants: Their Conservation and Sustainable Use. S. A. Ghazanfar and H. J. Beentje (eds.), pp 613-627. Proceedings XVIIth AETFAT Congress. Royal Botanic Gardens, Kew.

Rabesala Horning, N. 2008. Strong support for weak performance: Donor competition in Madagascar. African Affairs 107: 405-431. (doi:10.1093/afraf/adn036)

Razafindramiadana, L. 2009. Trafic de bois de rose. Pas de rapatriement de devises. L'Express de Madagascar 31 octobre 2009. <http://www.lexpressmada.com/display.php?p=display&id=30755> accessed 31 October 2009.

Schatz, G. E. 2001. Generic Tree Flora of Madagascar. Royal Botanic Gardens, Kew.

Schuurman D. 2009. Illegal logging of rosewood in the rainforests of north-east Madagascar. TRAFFIC Bulletin 22, 2: 49.

Stasse, A. 2002. La Filière Bois de Rose. Région d'Antalaha – Nord-est de Madagascar. Unpublished Master's thesis, Université de Montpellier, France.

Wilmé, L., Schuurman, D., Lowry II, P. P. and Raven, P. H. 2009. Precious trees pay off – but who pays? Poster prepared for the World Forestry Congress in Buenos Aires, Argentina, 18-23 October 2009.

SUPPLEMENTARY MATERIAL.

AVAILABLE ONLINE ONLY:

Poster titled ‹Precious Trees pay off - but who pays?› prepared by Lucienne Wilmé, Derek Schuurman, Porter P. Lowry II and Peter H. Raven for the World Forestry Congress held in Buenos Aires, October 2009.

Gastrointestinal parasite infection of the Gray mouse lemur (*Microcebus murinus*) in the littoral forest of Mandena, Madagascar: Effects of forest fragmentation and degradation

Brigitte M. Raharivololona[I] and Jörg U. Ganzhorn[II]

Correspondence:
Brigitte M. Raharivololona
Département d'Anthropologie et de Biologie Évolutive,Université d'Antananarivo, Antananarivo 101, Madagascar
E-mail:raharivololonabrigitte@yahoo.fr

ABSTRACT

Faecal material from 169 individuals of *Microcebus murinus* living in five littoral forest fragments was analyzed for gastrointestinal parasites. The fragments differed in size and forest quality. Gastrointestinal parasite infection of *M. murinus* was characterised using parasite species richness, the prevalence of parasites, and the intensity of infection expressed as the number of parasite eggs, larvae and cysts per gram of faeces. For this, a modification of the McMaster flotation egg counting technique was applied to analyze egg shedding. We recorded nine gastrointestinal parasite species in faecal samples of *Microcebus murinus*. In good quality forest lemurs from a smaller fragment had higher prevalences and intensities of infection of gastrointestinal nematodes and protozoans than animals from a larger forest fragment. In large forests, excretion of eggs from Ascarididae and tapeworms was higher in a degraded forest fragment than in a good quality forest fragment. This situation was reversed in small forest fragments with fewer eggs of *Suburula* nematodes and protozoans shed by lemurs in the degraded fragment than by lemurs from the good quality fragment. Our analyses are hampered by the fact that we had only one forest fragment per type of treatment. Keeping this limitation in mind, the results are consistent with other studies and indicate that forest degradation and fragmentation have marked effects on the level of parasitism of Madagascar's lemurs.

RÉSUMÉ

Des matières fécales de 169 individus de *Microcebus murinus* vivant dans cinq fragments de forêt littorale du sud de Madagascar ont été analysées par la méthode modifiée de flottaison de McMaster. Ces animaux avaient été capturés entre avril 2003 et octobre 2005. Les fragments de forêt diffèrent entre eux par la taille et le degré de dégradation. Pour étudier l'impact de la fragmentation et de la dégradation de la forêt sur l'infestation parasitaire de cette espèce de lémurien, trois critères ont été évalués qui sont le nombre d'espèces de parasite, la prévalence et l'intensité de l'infestation. Les fragments ayant des tailles différentes mais montrant un même type de dégradation ont fait l'objet d'une comparaison au même titre que des fragments présentant un même degré de dégradation mais de mêmes tailles. Neuf espèces de parasites gastro-intestinaux ont été recensées chez *Microcebus murinus* de la forêt de Mandena dont six nématodes avec une espèce non-identifiée de la famille des Ascarididae et de l'ordre des Strongylida, *Trichuris* sp., deux espèces d'Oxyuridae dont l'une est du genre *Lemuricola* et une autre qui n'est pas encore identifiée, *Subulura* sp., deux cestodes appartenant au genre *Hymenolepis* et un protozoaire de l'ordre des Coccidia. La fragmentation et la dégradation de la forêt de Mandena affectent le parasitisme de cette espèce de lémurien.

Les deux tendances qui ressortent de cette étude sont, d'une part, une augmentation de l'intensité et de la prévalence des parasites gastro-intestinaux de *Microcebus murinus* dans les plus petits fragments forestiers et d'autre part, une augmentation qui semble être en relation avec le degré de dégradation de la forêt dans les plus grands fragments. L'augmentation du nombre d'espèces de parasites avec la taille des fragments peut être une conséquence de la taille des fragments ou du nombre d'animaux échantillonnés. Dans les grands fragments, les microcèbes sont plus souvent infestés par les deux espèces de cestode lorsqu'ils sont dans des forêts dégradées que dans les fragments plus ou moins intacts. Dans les plus grandes parcelles forestières, la prévalence et l'intensité de l'infestation parasitaire sont plus élevées chez les microcèbes vivant dans les fragments très dégradés. Ce fait pourrait être dû à la réduction ou la perte de l'habitat associée à l'organisation sociale de l'animal car *M. murinus* dort en groupe pendant le jour, de sorte qu'une réduction de son habitat pourrait favoriser une augmentation des contacts interindividuels et la transmission de parasites, bien que l'infestation des microcèbes n'était pas liée à la densité des hôtes d'une manière significative. En connaissant l'effet néfaste des parasites, cette étude contribuerait à l'amélioration de la conservation de la biodiversité en relation avec les risques et les bénéfices des activités d'exploitation et de gestion de l'écosystème.

KEY WORDS: Lemurs, primates, gastrointestinal parasites, fragmentation, degradation.
MOTS CLEF : lémuriens, primates, parasites gastro-intestinaux, fragmentation, dégradation.

I Phone: +261 (0) 3240 60876
II Animal Ecology and Conservation, Hamburg University, Martin-Luther-King Platz 3, 20146 Hamburg, Germany. Phone +49 40 42838 4224, E-mail: ganzhorn@zoologie.uni-hamburg.de

INTRODUCTION

The outstanding biodiversity of Madagascar is threatened by the destruction of native habitats such as forest fragmentation, degradation and subsequent erosion (Mittermeier et al. 2004, Elmqvist et al. 2007, Harper et al. 2007, Allnutt et al. 2008). In addition to the destruction of habitat, native species can be affected by the transmission of disease (Wallis and Lee 1999, Smith et al. 2009). The effects of changes in the pathways of parasite transmission, changes in parasite prevalence in modified habitats, and the effects of newly introduced parasites on native species have received little attention in Madagascar even though there are signs of disease transmission from introduced to native species (Begon et al. 1999, Duplantier and Duchemin 2003, Duplantier et al. 2003), which might lead to population declines of the endemics (Goodman 1995). Host populations can be affected by parasites through a reduction in population growth (Hudson et al. 1998, Hochachka and Dhondt 2000), through reduced survival and decreased physical fitness (Chandra and Newberne 1977, Boyce 1990, Dobson and Hudson 1992, Hudson et al. 1992, Coop and Holmes 1996), or through reduced birth rates due to malformations and abortion (Chandra and Newberne 1977, Despommier et al. 1995).

Studies on gastrointestinal parasites of primates have focussed on haplorhine primates (Appleton et al. 1986, Eley et al. 1989, McGrew et al. 1989, Stoner 1996, Stuart et al. 1990, 1998, Müller-Graf et al. 1997, Ashford et al. 1990, 2000, Lilly et al. 2002, Hahn et al. 2003, Gillespie et al. 2004, 2005, Chapman and Huffman 2009). Prosimians' gastrointestinal parasites are less well studied. Some studies have been conducted on lemur parasites, but most studies have focussed on inventories and morphological descriptions (e.g., Chabaud and Choquet 1955, Chabaud and Brygoo 1956, Chabaud and Petter 1958, 1959, Chabaud et al. 1961a,b, 1964, 1965, Petter et al. 1972, Hugot et al. 1995, 1996, Randriamiadamanana 1998, Hugot and Baylac 2007, Rasambainarivo 2008). Few studies were based on animals in their natural habitat (Junge and Louis 2002, 2005, 2007, Junge and Sauther 2006). Schwitzer et al. (In press) compared the prevalence of gastrointestinal parasites in *Eulemur flavifrons* in primary and secondary forest in the Sahamalaza National Park of northwestern Madagascar. In their study, a higher percentage of lemurs were infected with gastrointestinal parasites in secondary than in primary forest. Irwin and Raharison (Submitted) summarize the current knowledge about endoparasites of lemurs in Madagascar. Raharivololona (2006, 2009) extends the previous knowledge on gastrointestinal parasites by data from a long-term study on *Microcebus murinus* from the littoral forest fragments of Mandena with additional information on the occurrence of these parasites in sympatric lemurs and other small mammals (Raharivololona et al. 2007). In these forests, Schad et al. (2004, 2005) found the highest parasite loads in mouse lemurs living in one of the smaller fragments. They were able to correlate the occurrence of parasites with specific alleles of the major histocompatibility complex. More recently Wright et al. (2009) analyzed the ectoparasite communities of *Propithecus edwardsi* in Ranomafana National Park. Ectoparasite infestation did not change much between primary and more degraded rain forest but changed significantly between the cool and the hot season.

Fragmentation of primary forests, degradation of habitats and conversion into anthropogenic landscapes is a rapid process in Madagascar (see references cited above). While the protected area system has been extended over the last few years in the wake of the Durban vision, the established protected areas risk to become more and more isolated due to development activities and climate change (Burney et al. 2004, Bodin et al. 2006, Hannah et al. 2008). Animals will then remain in the isolated fragments or have to use secondary and degraded corridors to move between primary forest sites. This situation leads to an increase in edge effects and possible disease transmission by non-forest or introduced species, such as rats, humans and other species associated with human activities. The question then is how animals are affected by fragmentation and degradation. To gain more insights into possible effects of these processes on lemurs we extend previous reports on the ecological context of the occurrence and intensity of infection by gastrointestinal parasites of *Microcebus murinus* living under different environmental conditions in the humid littoral forest of southeastern Madagascar (Schad et al. 2004, 2005, Raharivololona et al. 2007, Raharivololona and Ganzhorn In press, Ganzhorn et al. In press). In particular, we address the questions:

- Are parasite loads of *Microcebus murinus* related to host density?
- Do parasite loads differ in forest fragments of similar forest quality but of different size?
- Do parasite loads differ in forest fragments of similar size but different degrees of degradation?

METHODS

STUDY SPECIES. *Microcebus murinus*, the Gray mouse lemur, is a small (average 60 g) nocturnal and omnivorous lemur. It is widespread and not considered endangered. Its diet consists of insects, fruit, flowers, and leaves. They also eat sap, gum, secretions from homopteran larvae, and small vertebrates such as frogs, geckos, and chameleons. This lemur forages alone but congregates at daytime sleeping sites. The species is arboreal, polygynous, and distributed throughout western, southern, and southeastern Madagascar (Figure 1). They occur in primary, secondary, and disturbed forest habitats (Martin 1972, Petter et al. 1977, Lahann et al. 2006, Mittermeier et al. 2008).

STUDY SITE. The study was carried out in fragments M5, M13, M15, M16, and M20 of the littoral forest of Mandena, 12 km northeast of Tolagnaro at sites ranging in altitude from 0 to 20 m (Figure 1). Annual rainfall is about 1,600 mm (Vincelette et al. 2007a). The forest fragments differed in size and their degree of degradation. Vincelette et al. (2007b) measured the state of a given forest fragments in 50 m intervals along 50 m wide transects in each forest block. If the block was too narrow to include more than one transect, a single line was drawn with transects shorter than 50 m and perpendicular to the main line. The following data were obtained at each sampling position spaced 50 m apart and within the 50 x 50 m grid: General condition of the forest; signs of cutting (stumps) and fires; openings and agricultural areas; and observations of the vertical structure of the forest canopy level (upper, intermediary, or lower). Finally, the field observer evaluated, in a diagrammatic way, the canopy cover at the sampling position. The observer estimated the percentage of surface area occupied by the tree canopy within a 20 m radius of the sampling site. In cases where the canopy was continuous, represent-

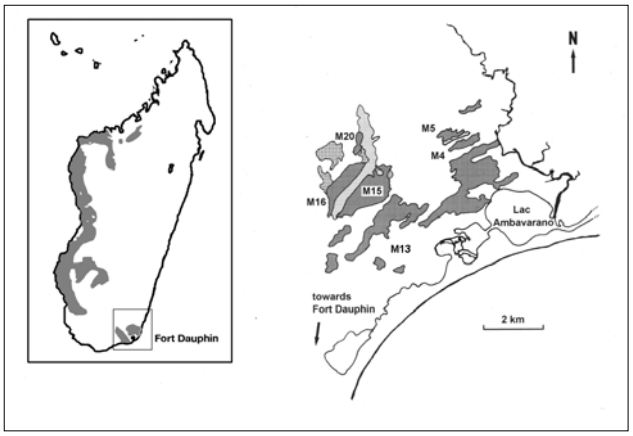


FIGURE 1. Location of study areas in the Tolagnaro region. The forest remnants are numbered and shown as dark shading. Eucalyptus plantations are crosshatched. Swamps with bordering Melaleuca (introduced) are marked with curved lines. The grey area in the insert map marks the distribution of *Microcebus murinus* on Madagascar (insert map from Ramon Hernando Orozco / Conservation International; detailed map modified from Ramanamanjato and Ganzhorn 2001).

ing 100 % cover, this corresponds to a littoral forest in good condition. The percentage canopy cover was then categorized in five classes of forest degradation (Vincelette et al. 2007b; Table 1). Additional measures to describe the vertical stratification of the forest blocks and schematic drawings are presented in Ganzhorn et al. (2007), Rabenantoandro et al. (2007) and Rasolofoharivelo (2007).

Fragments were classified as: M20: small and degraded / low quality forest; M13: large and degraded / low quality forest; M5: small and good quality forest (less degraded than M20; M20 underwent continuous degradation over the course of the study); and M15: large and good quality forest (less degraded than M13). Except for fragment M16, the state of the forest fluctuated only within a given category of degradation during the study period. The fragment M16 underwent degradation and subsequent recovery over the course of the study. In the previous analyses M16 had been combined with M15 as the two fragments can be considered to be contiguous even though a swamp separates them. However, we did record marked changes in the population density of *M. murinus* in M16 over time, which might have been linked to the degradation of M16 (but not in M15). Since the consequences of the ephemeral degradation for parasite infections are unclear, we did not consider M16 in the present analyses. However, the descriptive data of M16 are listed for comparison. M16 resembles M15 with respect to parasite prevalence and the intensity of infection. Therefore, pooling of M16 with M15 would have strengthened the results and conclusions based on M15 (Table 1).

ANIMAL CAPTURE. Small mammals were captured with Tomahawk and Sherman (Tomahawk Live Trap CO. Tomahawk, WI; H. B. Sherman Traps, Inc., Tallahassee, FL) live traps using standard procedures at permanent study sites set up in different forest fragments of Mandena (Ramanamanjato and Ganzhorn 2001). Traps baited with banana were set for four nights per month at 80 or 100 localities per fragment between April 2003 and October 2005. Trapping sessions rotated between fragments systematically to avoid effects of seasonality and to achieve similar trapping effort at each locality in each month. Our own trapping was discontinued from January to April when females had babies. Additional faecal samples (29 samples from M15, M16 and M20 of the 169 samples) were provided from animals caught by Petra Lahann, Nina Rüdel, Jörg Schüller and Björn Siemers. The samples collected by Petra Lahann had been collected in M15 between November 2003 and March 2004. Traps were checked in the morning. Trapped animals were released in bags to be sexed, measured, weighed, and marked permanently with subdermal transponders. Animals were released at the locality where they had been captured at the beginning of the night. Trapping and handling was authorized by permits issued by the Ministère de l'Environnement, des Eaux et Forêts Malgache.

Population densities (individuals per hectare) were measured as the number of animals caught per site by the size of the permanent study site. These densities fluctuated over the years. The low number of captures does not allow applying density calculations based on mark-recapture data. Population density estimates vary between 3 and 21 animals per hectare and increased from M5 – M13 – M20 – M15 – M16 (Ganzhorn et al. 2007). Total population size of the host was calculated by multiplying density estimated by the size of the forest fragment.

FAECAL SAMPLING AND ANALYSES. Fresh faeces were collected from handling bags or traps and stored in vials containing 4 % formalin (traps and handling bags were cleaned after use). A modification of the McMaster flotation egg counting technique (Sloss et al. 1994) was applied to analyze egg shedding which has been considered a valid method of evaluating worm burden in several studies (e.g., Gulland et al. 1993, Stear et al. 1995, Paterson et al. 1998, Coltman et al. 1999, Cassinello et al. 2001, Schwensow et al. 2007). For this, 300 mg of faeces were triturated in a beaker with 3 ml of a saturated potassium iodide solution (KI) with a specific weight of 1.5 g / ml. The mixture was poured through a tea strainer to eliminate non-digested large particles. The residue in

TABLE 1. Characteristics of fragments of the littoral forest of Mandena (as of the year 2000), trapping effort and capture results.

	Fragment					
	M5	M13	M15	M16	M20	Total
Size (ha)	28	80	113	75	15	
% Canopy cover in 2000	51-70 %	< 20 %	51-70 %	21-50 %	21-50 %	
Forest quality	Good	Poor	Good	Intermediate	Poor	
Number of trapnights	3,300	4,200	2,347	3,800	2,800	16,447
Number of faecal samples	28	64	82	174	79	427
Number of *M. murinus* (without recaptures)	14	24	54	47	30	169
Density of *M. murinus* (ind./ha)	4	6.2	9.7	13.3	9.7	

the tea strainer was washed with 1 ml of KI. The suspension was filled to a volume of 4.5 ml with the KI solution, stirred again and transferred to both chambers of a McMaster counting chamber with a pipette. The slide was transferred to a microscope and left alone for five minutes before examining. During this time, eggs, larvae and cysts float to the surface of the McMaster counting chambers. The slide was then examined with 100 x and 400 x magnification to identify and count all eggs, larvae and oocysts inside the ruled squares. This method was developed by Meyer-Lucht (2003) and has been applied successfully in a number of other studies (e.g., Meyer-Lucht and Sommer 2005, Schad et al. 2005). The procedures for parasite identification have been described previously (Raharivololona 2006, 2009). The assignment of eggs and larvae to some of the species listed in Table 2 has been verified by comparisons with adult parasites found in the digestive tract (Raharivololona 2009).

The analyses were based on the prevalence (= percentage of infected *Microcebus murinus*) of different nematode morphotypes in a population and the faecal egg count (FEC) value as measurements of the intensity of the parasite burden. For consistency with our previous papers we define FEC as the number of eggs and larvae found in one gram of faeces of one individual. This definition deviates from the generally accepted term, which includes only eggs. It is obtained by multiplying the number of eggs and larvae counted in the two chambers of Mc Master's cell by 50 (Euzéby 1981). Since *M. murinus* could be infested with parasites from other animals (such as from rats which share all parasites found in *M. murinus* [Raharivololona et al. 2007]) or some of the parasites excreted by *M. murinus* could be parasites from their invertebrate prey, precautions were taken to increase the probability that the parasites described were actual parasites of *M. murinus*. For this, some individuals of *M. murinus* were kept for four days in quarantine. Faecal samples were collected each morning and analyzed for parasites. Food passage time was investigated with markers and determined to be below 24 hours in all cases. Therefore all parasites found in the faeces of these animals after the second night were assumed to be genuine parasites of *M. murinus* and not temporary parasites from prey or accidental infections (Raharivololona 2009).

STATISTICS. For the present analyses each individual *Microcebus murinus* was used only once. For the quantification of parasite loads we used the faecal sample collected at the first capture of the animal. Data from recaptures were not considered for two reasons: First, most recaptures occurred within a single 4-night trapping session. Since traps were baited with banana and animals were fed banana while held in the traps, faeces consisted almost exclusively of banana the night after an animal had been caught. If an animal had been caught in 1-2 day intervals, the faeces were again different. Second, statistics would have been further complicated by varying recaptures of individuals in other months (with or without recaptures within these months). We are aware that we might lose information by not considering the data from the various recaptures, but the quality of data would not be the same for all data points, regardless of what kind of nested analyses we would apply. If a parasite species was not detected in the first sample, but was found later, it was not included in the present analyses. This approach matches the screening for parasites in most primate studies where repeated captures of the same individuals is not possible.

Since data deviated from normality we applied non-parametric statistics and restricted the analyses to single factor comparisons. For the analyses of the effects of fragment size, fragments were matched by the degree of degradation. For the analyses of the effect of degradation, fragments were matched by their size.

The statistical approach is a little bit misleading as we analyse data from four forest fragments, and use a series of pair-wise comparisons to compare pairs of fragments. Thus, in a rigorous statistical way, sample size equals 1 for each treatment. While the fragments vary in strategic ways (e.g. small degraded versus large degraded), any differences described in these pair-wise comparisons and linked to the variables 'forest size' and 'forest degradation' may be from the postulated source (e.g. fragment size) but could be due to something else entirely. Thus, the results have to be considered as 'indications' of possible effects of size and disturbance, but further study are necessary to verify this more directly.

RESULTS

In 16,447 trap nights we caught 169 individuals of *Microcebus murinus* in the five littoral forest fragments of Mandena (Table 1). These animals were infected with a total of nine gastrointestinal parasite species: Eight helminth species and one protozoan. The helminths included six nematodes: One species of Ascarididae and one of the order Strongylida, *Trichuris* sp., two species of Oxyuridae (*Lemuricola* sp. and one non-identified species), *Subulura* sp., and two cestodes (Platyhelminthes, genus *Hymenolepis*). The protozoan was a member of the Coccidia (Table 2). We consider all of these forms true parasites of *M. murinus*.

PARASITE LOADS AND HOST DENSITY. Though statistical analyses are hampered by the low number of fragments, the number of different parasite species found seems to increase with the number of individuals captured, but this trend was not significant (Tables 1, 2). Neither parasite prevalence nor the intensity of infection was correlated significantly with the density of *Microcebus murinus* according to Spearman rank correlations (Tables 1, 3, 4).

Subsequently we summarize the results of the pair-wise comparisons of the different aspects of parasite loads between fragments of different size and forest quality. The data and the results of the statistical comparisons are listed in Tables 3 and 4. Significant differences between fragments are highlighted in the tables and described in the text. Non-significant results are listed in the tables but not described in detail in the text.

EFFECT OF FRAGMENT SIZE IN GOOD QUALITY FOREST FRAGMENTS. The effect of forest and population size on the parasite load of *Microcebus murinus* was compared between the two good quality fragments M5 (small) and M15 (large).

Parasite species richness: On average, individual *Microcebus murinus* from the small fragment M5 harbor more parasite species than animals from the large fragment M15 (Mann Whitney U test: $z=2.25$, $p<0.05$; Figure 2).

Prevalence of parasites: Nematodes occurred in a higher percentage of *Microcebus murinus* individuals in M5 than in M15. This difference was not significant if based on M15 alone ($X^2=3.16$, $df=1$, $0.05 < p < 0.1$), but was significant if data from M16 were included ($X^2=4.37$, $df=1$, $p<0.05$). On a specific level, the preva-

TABLE 2. Species of gastrointestinal parasites of *Microcebus murinus* in different littoral forest fragments (+: present; -: absent).

	Fragment				
	M5	M13	M15	M16	M20
Size (ha)	28	80	113	75	15
Forest quality	Good	Poor	Good	Intermediate	Poor
Number of *M. murinus* captured	14	24	54	47	30
Nemathelminthes					
Ascarididae					
Ascarididae species	+	+	+	+	+
Subulura sp.	+	+	+	+	+
Strongylida					
Strongylida species	-	-	+	+	+
Trichuridae					
Trichuris sp.	+	-	+	-	+
Oxyuridae					
Lemuricola sp.	-	+	+	-	+
Oxyuridae species	+	-	+	+	+
Total number of nematode species	4	3	6	4	6
Plathelminthes					
Cestoda					
Hymenolepididae					
Hymenolepis sp1	+	+	+	+	+
Hymenolepis sp2	-	+	+	+	+
Total number of cestode species	1	2	2	2	2
Protozoa (Coccidia)	+	+	+	+	+
Total number of all parasite species	6	6	9	7	9

TABLE 3. Prevalence (%) of different gastrointestinal parasite species in *Microcebus murinus* in five littoral forest fragments. Differences between fragments were evaluated with Chi-Square and Fisher's Exact tests; for Chi-square tests Chi-square values and significance categories are listed; for Fisher's Exact test only p-values are listed: * $p < 0.05$; ** $p < 0.01$.

	Fragment					Comparison			
	M5	M13	M15	M16	M20	M5 - M15	M20 - M13	M15 - M13	M5- M20
Number of *M. murinus*	14	24	54	47	30				
Nemathelminthes									
Ascarididae									
Ascarididae species	21.4	37.5	11.1	17	30	0.38	$X^2 = 0.34$	0.01*	0.72
Subulura sp.	71.4	20.8	37	44.7	23.3	$X^2 = 4.43$*	$X^2 = 0.05$	$X^2 = 2.00$	$X^2 = 9.31$**
Strongylida									
Strongylida species	0	0	11.1	10.6	6.7	0.33	0.5	0.17	1
Trichuridae									
Trichuris sp.	14.2	0	7.4	0	10	0.6	0.25	0.31	0.65
Oxyuridae									
Lemuricola sp.	0	4.2	9.3	0	3.3	0.58	1	0.66	1
Oxyuridae species	7.14	0	3.7	8.5	20	0.51	0.02*	1	0.4
Prevalence of all nematodes	85.7	45.8	50	57.5	56.7	$X^2 = 3.16$*	$X^2 = 0.63$	$X^2 = 0.12$	0.09
Plathelminthes									
Cestoda									
Hymenolepididae									
Hymenolepis sp1	21.4	33.3	7.4	38.3	26.7	0.15	X2 = 0.28	0.006**	1
Hymenolepis sp2	0	8.3	1.9	2.1	6.7	1	1	0.22	1
Prevalence of all cestodes	21.4	37.5	7.4	40.4	33.3	0.15	$X^2 = 0.10$	0.002**	0.5
Protozoa (Coccidia)	85.7	58.3	44.4	46.8	40	$X^2 = 5.18$*	$X^2 = 1.80$	$X^2 = 1.28$	$X^2 = 8.05$**
Prevalence of all gastrointestinal parasites	92.9	87.5	74.1	78.7	83.3	0.13	p = 0.72	$X^2 = 1.76$	0.65

lence of *Subulura* sp. and of Coccidia were higher in M5 than in M15 (X^2=4.43 and X^2=5.18, df=1, $p < 0.05$, respectively; Table 3).

Intensity of infection: Faeces of *Microcebus murinus* from M5 contained higher concentrations of nematode eggs and larvae, particularly of *Subulura* sp. and cysts of *Coccidia* than those of animals from M15 ($z = 2.48$, $p = 0.013$; $z = 2.20$, $p = 0.028$; $z = 3.47$, $p = 0.001$, respectively). Considering the total parasite community, mouse lemurs from M5 showed higher numbers of helminth eggs and larvae plus protozoan cysts than individuals from M15 ($z = 3.55$, $p < 0.001$; Table 4).

Effect of fragment size in degraded forest fragments The effect of forest and population size on parasite loads of *Microcebus murinus* was compared between the two degraded fragments M20 (small) and M13 (large).

Parasite species richness: The average number of parasites per individual *Microcebus murinus* did not differ between different sized degraded forest fragments (Figure 2).

Prevalence of parasites: Among the nematodes, only the non-identified species of Oxyuridae differed significantly in their prevalence between M20 and M13, reaching higher prevalence in the smaller fragment (Fisher's exact test: $p = 0.023$; Table 3).

Intensity of infection: As a logical consequence of the finding that the prevalence of oxyurid nematodes was 0 in M13, the higher prevalence of the oxyurid nematode in M20 was paralleled by a higher faecal egg and larvae count in this fragment than in M13 ($z = 2.30$, $p < 0.05$) with a maximum count of 50 eggs and larvae / g faeces in *Microcebus murinus* from M20 (Table 4).

EFFECT OF FOREST DEGRADATION IN LARGE FOREST FRAGMENTS. The effect of forest degradation in large forest fragments was based on the comparison of the parasite loads of *Microcebus murinus* in M13 (poor quality) and M15 (good quality).

Parasite species richness: Lemurs from the degraded fragment M13 are significantly more often infected by both species of cestodes (Hymenolepis spp.) than animals from the higher quality forest fragment M15 (Mann Whitney U test: $z = 3.22$, $p < 0.001$). Given the uncertainties associated with quantitative analyses of cestodes, this result might need further study.

TABLE 4. Number of parasite eggs and larvae (in case of helminths) or cysts (in case of Protozoa) per gram of faecal materials in *M. murinus* of different fragments. Values are medians; minima and maxima in brackets. Differences between fragments were evaluated with Mann-Whitney U test; values are z-values and associated significance: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

	Fragment					Comparison			
	M5	M13	M15	M16	M20	M5 - M15	M20 - M13	M15 - M13	M5 - M20
Number of *M. murinus*	14	24	54	47	30				
Nemathelminthes									
Ascarididae									
Ascarididae species	0 [0-11900]	0 [0-25100]	0 [0-8400]	0 [0-2850]	0 [0-12700]	1	0.59	2.63**	0.56
Subulura sp.	50 [0-600]	0 [0-150]	0 [0-800]	0 [0-750]	0 [0-550]	2.20*	0.4	1.41	2.68**
Strongylida									
Strongylida species	0 [0-0]	0 [0-0]	0 [0-50]	0 [0-250]	0 [0-50]	1.3	1.28	1.69	0.98
Trichuridae									
Trichuris sp.	0 [0-50]	0 [0-0]	0 [0-550]	0 [0-0]	0 [0-650]	0.68	1.58	1.36	0.32
Oxyuridae									
Lemuricola sp.	0 [0-0]	0 [0-50]	0 [0-50]	0 [0-0]	0 [0-200]	1.17	0.13	0.77	0.68
Oxyuridae species	0 [0-50]	0 [0-0]	0 [0-50]	0 [0-50]	0 [0-150]	0.55	2.30*	0.94	1.13
All nematodes	150 [0-11900]	0 [0-25150]	25 [0-9150]	50 [0-2900]	75 [0-13150]	2.48**	0.38	0.48	0.93
Plathelminthes									
Cestoda									
Hymenolepididae									
Hymenolepis sp1	0 [0-5550]	0 [0-16800]	0 [0-4500]	0 [0-59350]	0 [0-8400]	1.51	0.16	2.88**	0.64
Hymenolepis sp2	0 [0-0]	0 [0-3000]	0 [0-1000]	0 [0-1000]	0 [0-50]	0.51	0.31	1.4	0.98
All cestodes	0 [0-5550]	0 [0-16800]	0 [0-4500]	0 [0-59350]	0 [0-8400]	1.47	0.35	3.20***	0.81
Protozoa (Coccidia)	5300 [0-687600]	75 [0-159600]	0 [0-39400]	0 [0-525600]	0 [0-148800]	3.47***	1.18	1.44	3.06**
All parasites (eggs, larvae and cysts)	9725 [0-688200]	675 [0-184750]	200 [0-39400]	1300 [0-526200]	200 [0-161950]	3.55***	0.38	1.93*	2.50**

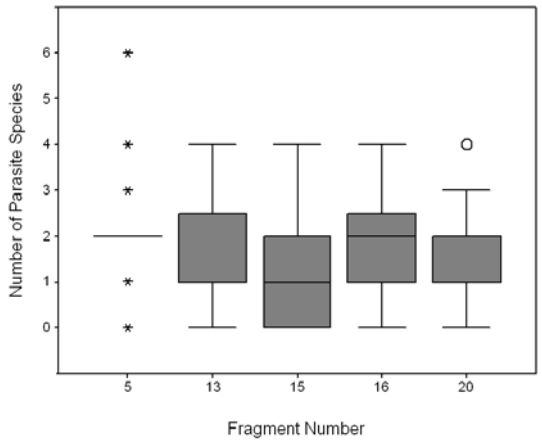


FIGURE 2. Number of gastrointestinal parasite species in individual *Microcebus murinus* in different forest fragments. Values are medians, quartiles and ranges.

Prevalence of parasites: Among the nematodes, Ascarididae showed higher prevalence in the degraded M13 than in the intact forest of M15 ($p < 0.05$). The cestode community in general and *Hymenolepis* sp1 in particular were significantly more abundant in M13 than in M15 ($p < 0.05$; Table 3).

Intensity of infection: The higher prevalence of Ascarididae in M13 was associated with higher counts of eggs of this parasite in M13 than in M15 ($z = 2.63$; $p < 0.01$). Mouse lemurs from M13 shed significantly more parasite eggs, larvae and cysts than animals from M15 ($z = 1.93$, $p < 0.05$). Apart from the higher egg counts of Ascarididae, this was due to higher counts of cestode eggs in general, and in particular of *Hymenolepis* sp1. (all cestodes: $z = 3.20$, $p = 0.001$; *Hymenolepis* sp1: $z = 2.88$, $p < 0.01$; Table 4).

EFFECT OF FOREST DEGRADATION IN SMALL FOREST FRAGMENTS. The effect of forest degradation in small forest fragments was based on the comparison of the parasite loads of *Microcebus murinus* in M20 (poor quality) and M5 (good quality).

Parasite species richness: The average number of parasites per individual *Microcebus murinus* did not differ between small forest fragments with different forest quality (Figure 2).

Prevalence of parasites: The prevalence of *Subulura* sp. and of Coccidia was significantly higher in the less degraded fragment M5 than in the degraded fragment M20 ($X^2 = 9.31$, $p < 0.01$ and $X^2 = 8.05$, $p < 0.01$, respectively; Table 3).

Intensity of infection (Faecal Egg Count): Again, the difference in prevalence was mirrored by differences in the intensity of infection. These differences were significant for the parasite community in general ($z = 2.50$, $p < 0.05$) as well as for *Subulura* sp. ($z = 2.68$, $p < 0.01$) and Coccidia ($z = 3.06$, $p < 0.01$; Table 4).

DISCUSSION

Madagascar's forests suffer from fragmentation and degradation (Mittermeier et al. 2004, Elmqvist et al. 2007, Harper et al. 2007, Allnutt et al. 2008). Apart from causing reductions in population size, these processes increase the exposure of native forest animals to more generalized species, which can use the anthropogenic matrix around the remaining fragments and act as vectors for diseases. Despite an early warning of possible negative effects of the infection of native mammals by diseases carried by introduced species (Goodman 1995), little work has been done to assess these effects (Duplantier and Duchemin 2003, Duplantier et al. 2003).

A study on the occurrence of gastrointestinal parasites in a small mammal community of the littoral forest ecosystem showed that rats (*Rattus rattus*) share many gut parasites with the native small mammal species (Raharivololona et al. 2007). Since rats also use non-forested areas, they can spread parasites from one forest fragment to another. The results of the study illustrated that forest degradation was an important component of disease transmission and favored the spread of diseases. However, sample size was small and statistical significance weak in the previous analysis. Therefore we extended the database. Jovani and Tella (2006) discuss possible problems associated with sample size in parasitological studies. They conclude that a sample size around 15 represents a reasonable number to maintain an acceptable level of uncertainty. Our sample sizes match this recommendation, but we certainly cannot exclude artifacts.

In principle, the results of the previous study were confirmed by the additional data presented here. Lemurs from large fragments (M15 and M13) had lower parasite loads than animals from corresponding smaller fragments (M5 and M20). This also matches the results of studies on mainland Africa where gastrointestinal parasite load of colobus monkeys from Kibale National Park in Uganda was negatively correlated to the size of the forest fragments (Gillespie and Chapman 2006). Despite their lower parasite loads on an individual level, more parasite species were found in the larger fragments as a whole. This may be a consequence of the larger samples of hosts (more individuals) caught in the larger fragments.

The effect of degradation was not so clear. Results from Kibale in Uganda suggest that the prevalence of parasites should be higher in degraded than in non-degraded forests (Gillespie and Chapman 2006). Schwitzer et al. (In press) also reported higher parasite prevalence in *Eulemur macaco flavifrons* in degraded than in intact forests. This expectation was confirmed when comparing large fragments in Mandena. Here, forest degradation was linked to increased parasite load in the degraded fragment. However, in our study, the result was reversed when comparing degraded and less degraded small fragments. A possible interpretation could be that lemurs in small fragments have more parasites anyhow and that the size effect masks the effect of degradation in small fragments. But then we would expect similar levels of parasitism in both small fragments. The situation might be complicated further by social interactions and population densities. In general, the transmission of diseases increases with the number of social contacts, either due to the animals' social system (e.g., group living) or with increasing population density (Anderson and May 1979, 1991, Freeland 1976, Davies et al. 1991, Phillippi and Clarke 1992, Côté and Poulin 1995, Loehle 1995, Morand 2000, Hudson et al. 2002, Altizer et al. 2003, Nunn et al. 2003). Absolute population densities of *Microcebus murinus* are unknown for the different fragments, but trapping success was lower in M5 compared to M20, indicating higher population densities in M20 than in M5 (Table 1). This higher population density might have led to higher contact frequencies and thus increased disease transmission between *M. murinus* in M20 compared to M5. Thus, population characteristics of the host also do not match the expectations. In contrast, lemur densities

seem to be very similar in M13 and M15 (Ganzhorn et al. 2007) or might be even lower in M13 than in M15 (Table 1). Based on the results from other studies, host density and encounter rates might act as confounding factors. Their consequences for the situation in Mandena remain unknown.

In conclusion, the intensity and prevalence of gastrointestinal parasites of *Microcebus murinus* are elevated in small forest fragments and seem to increase with the degree of forest degradation in larger fragments. Since mouse lemurs share some of their gastrointestinal parasites with other small mammals, including introduced rats, it is likely that this increased infestation is driven by multiple factors, including fragment size and disturbance. Additionally, local ecological factors such as increased disease transmission through introduced species and crowding effects may also be important factors affecting parasite species richness, prevalence and egg counts.

ACKNOWLEDGMENTS

The study has been conducted under the Accord de Collaboration between the Université d'Antananarivo (Département de Biologie Animale and Département d'Anthropologie et de Biologie Évolutive) and Hamburg University. It is part of the biodiversity assessment and environmental impact studies of the littoral forest fragments initiated by QIT Madagascar Minerals (QMM). We thank Refaly Ernest for assistance with the fieldwork; Manon Vincelette, Jean-Baptiste Ramanamanjato, and their environmental and conservation team as well as other staff of QMM for technical assistance and help with logistics; Prof. Simone Sommer, Jan Axtner, Yvonne Meyer-Lucht and Nina Schwensow, (now at the Institute for Zoo and Wildlife Research, Berlin), and the staff at the Department of Animal Ecology and Conservation, Hamburg University; Dr. Frédéric Ariey and the Malaria Department of the Institut Pasteur de Madagascar; Dr. Rakotondravao, Gervais Randrianarivo and the Département de Recherches Zootechniques et Vétérinaires / FOFIFA for help and assistance in the laboratory analyses. We also thank Prof. D. W. Büttner (Bernhard Nocht Institute, Hamburg), Prof. Alain G. Chabaud, Dr. Odile Bain, and Dr. Marie-Claude Durette-Desset, Dr. J. P. Hugot (Muséum National d'Histoire Naturelle, Paris), Dr. Thomas R. Gillespie (Dept. Zoology at Florida State University), and Dr. David Modrý (Dept of Parasitology, University of Veterinary and Pharmaceutical Sciences, Czech Republic) for their advice. Patrick Waeber, Lucienne Wilmé and three reviewers provided excellent comments and advice on a previous version of the manuscript. Stephen Nash provided the map. This study was funded by the Margot Marsh Biodiversity Foundation, QMM, the German Research Foundation (DFG, Ga 342 / 14), and the German Academic Exchange Service (DAAD).

REFERENCES

Allnutt, T. F., Ferrier, S., Manion, G., Powell, G. V. N., Ricketts, T. H., Fisher, B. L., Harper, G. J., Irwin, M. E., Kremen, C., Labat, J.-N., Lees, D. C., Pearce, T. A. and Rakotondrainibe, F. 2008. A method for quantifying biodiversity loss and its application to a 50-year record of deforestation across Madagascar. Conservation Letters 1, 4: 173-181. (doi:10.1111/j.1755-263X.2008.00027.x)

Altizer, S., Nunn, C. L., Thrall, P. H., Gittleman, J. L., Antonovics, J., Cunningham, A. A., Dobson, A. P., Ezenwa, V., Jones, K. E., Pedersen, A. B., Poss, M. and Pulliam, J. R. C. 2003. Social organization and parasite risk in mammals: Integrating theory and empirical studies. Annual Reviews in Ecology, Evolution, and Systematics 34: 517-547. (doi:10.1146/annurev.ecolsys.34.030102.151725)

Anderson, R. M. and May, R. M. 1979. Population biology of infectious diseases. Nature 280: 361-367. (doi:10.1038/280361a0)

Anderson, R. M. and May, R. M. 1991. Infectious Diseases of Humans: Dynamics and Control. Oxford University Press, Oxford.

Appleton, C. C., Henzi, S. P., Whitten, A. and Byrne, R. 1986. The gastro-intestinal parasites of *Papio ursinus* from the Drakensberg Mountains, Republic of South Africa. International Journal of Primatology 7, 5: 449-456. (doi: 10.1007/BF02693656)

Ashford, R. W., Reid, G. D. and Butynski, T. M. 1990. The intestinal faunas of man and mountain gorillas in a shared habitat. Annals of Tropical Medicine and Parasitology 84, 4: 337-340.

Ashford, R. W., Reid, G. D. F. and Wrangham, R. W. 2000. Intestinal parasites of the chimpanzee *Pan troglodytes*, in Kibale Forest, Uganda. Annals of Tropical Medicine and Parasitology 94, 2: 173-179. (doi:10.1080/00034980057518)

Begon, M., Hazel, S. M., Baxby, D., Bown, K., Cavanagh, R., Chantrey, J., Jones, T. and Bennett, M. 1999. Transmission dynamics of a zoonotic pathogen within and between wildlife host species. Proceedings of the Royal Society of London, B 266: 1939-1945. (doi:10.1098/rspb.1999.0870)

Bodin, Ö., Tengö, M., Norman, A., Lundberg, J. and Elmqvist T. 2006. The value of small size: loss of forest patches and ecological thresholds in southern Madagascar. Ecological Applications 16, 2: 440-451.

Boyce, M. S. 1990. The red queen visits sage grouse leks. American Zoologist 30, 2: 263-270. (doi:10.1093/icb/30.2.263)

Burney, D. A., Pigott Burney, L., Godfrey, L. R., Jungers, W. L., Goodman, S. M., Wright, H. T. and Jull, A. J. T. 2004. A chronology for late prehistoric Madagascar. Journal of Human Evolution 47: 25-63 (doi:10.1016/j.jhevol.2004.05.005).

Cassinello, J., Gomendio, M. and Roldan, E. R. S. 2001. Relationship between coefficient of inbreeding and parasite burden in endangered gazelles. Conservation Biology 15, 4: 1171-1174. (doi:10.1046/j.1523-1739.2001.0150041171.x)

Chabaud, A. G. & Brygoo, E. R. 1956. Description de *Rictularia lemuri* n. sp. (Nematoda: Thelaziidae). Mémoires de l'Institut Scientifique de Madagascar 11, série A: 43-49.

Chabaud, A. G. & Choquet, M. T. 1955. Deux nématodes parasites de lémurien. Annales de Parasitologie 30, 4: 329-338.

Chabaud, A. G. & Petter, A. J. 1958. Les nématodes parasites de lémuriens malgaches. Mémoires de l'Institut Scientifique de Madagascar 12, série A: 139-158.

Chabaud, A. G. & Petter, A. J. 1959. Les nématodes parasites de lémuriens malgaches. II. Un nouvel oxyure: *Lemuricola contagiosus.* Mémoires de l'Institut Scientifique de Madagasacar 13, série A: 127-132.

Chabaud, A. G., Petter, A. J. & Golvan, Y. 1961a. Les nématodes parasites de lémuriens malgaches. III. Collection récoltée par M. et Mme Francis Petter. Annales de Parasitologie 36, 1-2: 113-126.

Chabaud, A. G., Brygoo, E. R. & Petter, A. J. 1961b. Les nématodes parasites de lémuriens malgaches. IV. Description de deux nouveaux genres et observations sur *Protofilaria furcata* Chandler. Bulletin du Muséum National d'Histoire Naturelle 33, 2e série 5: 532-544.

Chabaud, A. G., Brygoo, E. R. & Petter, A. J. 1964. Les nématodes parasites de lémuriens malgaches. V. Nématodes de *Daubentonia madagascariensis*. Vie et Milieu, Suppl. n° 17: 205-212.

Chabaud, A. G., Brygoo, E. R. & Petter, A. J. 1965. Les nématodes parasites de lémuriens malgaches. VI. Description de six espèces nouvelles et conclusions générales. Annales de Parasitologie 40, 2: 181-214.

Chandra, R. K. and Newberne, P. M. 1977. Nutrition, Immunity and Infection. Plenum Press, New York.

Chapman, C. and Huffman, M. A. 2009. Primates and their Parasites. Cambridge University Press, Cambridge.

Coltman, D. W., Pilkington, J. G., Smith, J. A. and Pemberton, J. M. 1999. Parasite-mediated selection against inbred Soay sheep in a free-living, island population. Evolution 53, 4: 1259-1267.

Coop, R. L. and Holmes, P. H. 1996. Nutrition and parasite interaction. International Journal for Parasitology 26, 8-9: 951-962. (doi:10.1016/S0020-7519(96)80070-1)

Côté, I. M. and Poulinb, R. 1995. Parasitism and group size in social animals: a meta-analysis. Behavioral Ecology 6, 2: 159-165. (doi:10.1093/beheco/6.2.159)

Davies, C. R., Ayres, J. M., Dye, C. and Deane, L. M. 1991. Malaria infection rate of Amazonian primates increases with body weight and group size. Functional Ecology 5, 5: 655-662.

Despommier, D. D., Gwazda, R. W. and Hotez, P. J. 1995. Parasitic Diseases. Springer-Verlag, New York.

Dobson, A. P. and Hudson, P. J. 1992. Regulation and stability of a free-living host-parasite system: *Trichostrongylus tenuis* in red grouse. II. Population models. Journal of Animal Ecology 61, 2: 487-498.

Duplantier, J.-M. and Duchemin, J.-B. 2003. Human diseases and introduced small mammals. In: The Natural History of Madagascar, S. M. Goodman and J. Benstead (eds.), pp 158-161. The University of Chicago Press, Chicago.

Duplantier, J.-M., Catalan, J., Orth, A., Grolleau, B. and Britton-Davidian, J. 2003. Systematics of the black rat in Madagascar: Consequences for the transmission and distribution of plague. Biological Journal of the Linnean Society 78, 3: 335-341. (doi:10.1046/j.1095-8312.2003.00142.x)

Eley, R. M., Strum, S. C., Muchemi, G. and Reid, G. D. F. 1989. Nutrition, body condition, activity patterns and parasitism of free-ranging troops of olive baboons (*Papio anubis*) in Kenya. American Journal of Primatology 18, 3: 209-219. (doi:10.1002/ajp.1350180304)

Elmqvist, T., Pyykönen, M., Tengö, M., Rakotondrasoa, F., Rabakonandrianina, E. and Radimilahy, C. 2007. Patterns of loss and regeneration of tropical dry forest in Madagascar: The social institutional context. PloS ONE 2, 5: e402. (doi:10.1371/journal.pone.0000402)

Euzéby, J. 1981. Diagnostic expérimental des helminthoses animales. Tome 1. Éditions Informations Techniques des Services Vétérinaires, Ministère de l'Agriculture, Paris.

Freeland, W. J. 1976. Pathogens and the evolution of primate sociality. Biotropica 8, 1: 12-24.

Ganzhorn, J. U., Andrianasolo, T., Andrianjazalahatra, T., Donati, G., Fietz, J., Lahann, P., Norscia, I., Rakotondranary, J., Rakotondratsima, B., Ralison, J., Ramarokoto, R. E. A. F., Randriamanga, S., Rasarimanana, S., Rakotosamimanana, B., Ramanamanjato, J.-B., Randria, G. F. N., Rasolofoharivelo, T. M., Razanahoera-Rakotomalala, M. R., Schmid, J. and Sommer, S. 2007. Lemurs in evergreen littoral forest fragments. In: Biodiversity, Ecology, and Conservation of Littoral Forest Ecosystems in Southeastern Madagascar, Tolagnaro (Fort Dauphin). J. U. Ganzhorn, S. M. Goodman and M. Vincelette (eds.), pp 247-258. Smithsonian Institution, Washington D.C.

Ganzhorn, J. U., Hapke, A., Lahann, P., Raharivololona, B. M., Ramanamanjato, J.-B., Refaly, E., Schmid, J., Schad, J. and Sommer, S. In press. Population genetics, parasitism and long-term population dynamics of *Microcebus murinus* in littoral forest fragments of south-eastern Madagascar. In: Leaping Ahead: Advances in Prosimian Biology, J. Masters, M. Gamba and F. Génin (eds.). Springer, Heidelberg.

Gillespie, T. R. and Chapman, C. A. 2006. Prediction of parasite infection dynamics in primate metapopulations based on attributes of forest fragmentation. Conservation Biology 20, 2: 441-448. (doi:10.1111/j.1523-1739.2006.00290.x)

Gillespie, T. R., Greiner, E. C. and Chapman, C. A. 2004. Gastrointestinal parasites of the guenons of western Uganda. Journal of Parasitology 90, 6: 1356-1360. (doi:10.1645/GE-311R)

Gillespie, T. R., Greiner, E. C. and Chapman, C. A. 2005. Gastrointestinal parasites of the colobus monkeys of Uganda. Journal of Parasitology 91, 3: 569-573. (doi:10.1645/GE-434R)

Goodman, S. M. 1995. *Rattus* on Madagascar and the dilemma of protecting the endemic rodent fauna. Conservation Biology 9, 2: 450-453. (doi:10.1046/j.1523-1739.1995.9020450.x)

Gulland, F. M. D., Albon, S. D., Pemberton, J. M., Moorcroft, P. R. and Clutton-Brock, T. H. 1993. Parasite associated polymorphism in a cyclic ungulate population. Proceedings of the Royal Society of London B 254, 1339: 7-13. (doi:10.1098/rspb.1993.0119)

Hahn, N. E., Proulx, D., Muruthi, P. M., Alberts, S. and Altmann, J. 2003. Gastrointestinal parasites in free-ranging Kenyan baboons (*Papio cynocephalus* and *P. anubis*). International Journal of Primatology 24, 2: 271-279. (doi:10.1023/A:1023092915171)

Hannah, L., Dave, R., Lowry II, P.P., Andelman, S., Andrianarisata, M., Andriamaro, L., Cameron, A., Hijmans, R., Kremen, C., MacKinnon, J., Randrianasolo, H. H., Andriambololonera, S., Razafimpahanana, A., Randriamahazo, H., Randrianarisoa, J., Razafinjatovo, P., Raxworthy, C., Schatz, G. E., Tadross, M. and Wilmé, L. 2008. Climate change adaptation for conservation in Madagascar. Biology Letters 4: 590-594.

Harper, G. J., Steininger, M. K., Tucker, C. J., Juhn, D. and Hawkins, F. 2007. Fifty years of deforestation and forest fragmentation in Madagascar. Environmental Conservation 34: 325-333. (doi:10.1017/S0376892907004262)

Hochachka, W. M. and Dhondt, A. A. 2000. Density dependent decline of host abundance resulting from a new infectious disease. Proceedings of the National Academy of Science of the United States of America 97, 10: 5303-5306. (doi:10.1073/pnas.080551197)

Hudson, P. J., Dobson, A. P. and Newborn, D. 1992. Do parasites make prey vulnerable to predation: Red grouse and parasites. Journal of Animal Ecology 61, 3: 681-692.

Hudson, P. J., Dobson, A. P. and Newborn, D. 1998. Prevention of population cycles by parasite removal. Science 282, 5397: 2256-2258. (doi:10.1126/science.282.5397.2256)

Hudson, P. J., Rizzoli, A., Grenfell, B. T., Heesterbeek, H. and Dobson, A. P. 2002. The Ecology of Wildlife Diseases. Oxford University Press, Oxford, United Kingdom.

Hugot, J.-P. and Baylac, M. 2007. Shape patterns of genital papillae in pinworms (Enterobiinae, Oxyurida, Nematoda) parasite of primates: A landmark analysis. Infection, Genetics and Evolution 7, 2: 168-179. (doi:10.1016/j.meegid.2006.08.001)

Hugot, J.-P., Morand, S. and Gardner, S. L. 1995. Morphology and morphometrics of three oxyurids parasitic in primates with a description of *Lemuricola microcebi* n. sp. International Journal for Parasitology 25, 9: 1065-1075. (doi:10.1016/0020-7519(95)00021-S)

Hugot, J.-P., Gardner, S. L. and Morand, S. 1996. The Enterobiinae subfam. nov. (Nematoda, Oxyurida) pinworm parasites of primates and rodents. International Journal for Parasitology 26, 2: 147-159. (doi:10.1016/0020-7519(95)00108-5)

Irwin, M. T. and Raharison, J.-L. In press. A review of the endoparasites of the lemurs of Madagascar. Malagasy Nature.

Jovani, R. and Tella, J. L. 2006. Parasite prevalence and sample size: misconceptions and solutions. Trends in Parasitology 22, 5: 214-218. (doi:10.1016/j.pt.2006.02.011)

Junge, R. E. and Louis, E. E. 2002. Medical evaluation of free-ranging primates in Betampona reserve, Madagascar. Lemur News 7: 23-25.

Junge, R. E. and Louis, E. E. 2005. Preliminary biomedical evaluation of wild ruffed lemurs (*Varecia variegata* and *V. rubra*). American Journal of Primatology 66, 1: 85-94. (doi:10.1002/ajp.20129)

Junge, R. E. and Louis, E. E. 2007. Biomedical evaluation of black lemurs (*Eulemur macaco macaco*) in Lokobe Reserve, Madagascar. Journal of Zoo and Wildlife Medicine 38, 1: 67-76. (doi:10.1638/06-006.1)

Junge, R. E. and Sauther, M. L. 2006. Overview on the health and disease ecology of wildlemurs: Conservation implications. In: Lemurs: Ecology and Adaptation. L. Gould and M. L. Sauther (eds.), pp 423-440. Springer, New York.

Lahann, P., Schmid, J. and Ganzhorn, J. U. 2006. Geographic variation in populations of *Microcebus murinus* in Madagascar: Resource seasonality or Bergmann's rule? International Journal of Primatology 27, 4: 983-999. (doi:10.1007/s10764-006-9055-y)

Lilly, A. A., Mehlman, P. T. and Doran, D. 2002. Intestinal parasites in gorillas, chimpanzees, and humans at Mondika Research Site, Dzanga-Ndoki National Park, Central African Republic. International Journal of Primatology 23, 3: 555-573. (doi:10.1023/A:1014969617036)

Loehle, C. 1995. Social barriers to pathogen transmission in wild animal populations. Ecology 76, 2: 326-335. (doi:10.2307/1941192)

Martin, R. D. 1972. A preliminary field study of the lesser mouse lemur (*Microcebus murinus* J. F. Miller 1777). Zeitschrift für Tierpsychologie 9: 43-89.

McGrew, W. C., Tutin, C. E. G., Collins, D. A. and File, S. K. 1989. Intestinal parasites of sympatric *Pan troglodytes* and *Papio* spp. at two sites: Gombe (Tanzania) and Mt. Assirik (Senegal). American Journal of Primatology 17, 2: 147-155. (doi: 10.1002/ajp.1350170204)

Meyer-Lucht, Y. 2003. Einfluss von Verstädterung auf Populationsstruktur, genetische Variabilität und Parasitenbefall bei der Gelbhalsmaus (*Apodemus flavicollis*). Diploma thesis, Universität Hamburg, Germany.

Meyer-Lucht, Y. and Sommer, S. 2005. MHC diversity and the association to nematode parasitism in the yellow-necked mouse (*Apodemus flavicollis*). Molecular Ecology 14, 7: 2233-2243. (doi:10.1111/j.1365-294X.2005.02557.x)

Mittermeier, R. A., Langrand, O., Lowry II, P. P., Schatz, G., Gerlasch, J., Goodman, S., Steininger, M., Hawkins, F., Raminosoa, N., Ramilijaona, O., Andriamaro, L., Randrianasolo, H., Rabarison, H. and Rakotobe, Z. L. 2004. Madagascar and the Indian Ocean Islands. In: Hotspots Revisited. R. A. Mittermeier, P. Gil, M. Hoffmann, J. Pilgrim, T. Brooks, C. Goetsch Mittermeier, J. Lamoreux and G. da Fonseca (eds.), pp 138-144. Cemex, Mexico.

Mittermeier, R. A., Ganzhorn, J. U., Konstant, W. R., Glander, K. E., Tattersall, I., Groves, C. P., Rylands, A. B., Hapke, A., Ratsimbazafy, J., Mayor, M. I., Louis, E. E. J., Rumpler, Y., Schwitzer, C. and Rasoloarison, R. M. 2008. Lemur diversity in Madagascar. International Journal of Primatology 29: 1607-1656.

Morand, S. 2000. Wormy world: comparative tests of theoretical hypotheses on parasite species richness. In: Evolutionary Biology of Host-Parasite Relationships. R. Poulin, S. Morand and A. Skorping (eds.), pp 63-79. Elsevier, Amsterdam.

Müller-Graf, C. D. M., Collins, D. A., Packer, C. and Woolhouse, M. E. J. 1997. *Schistosoma mansoni* infection in a natural population of olive baboons (*Papio cynocephalus anubis*) in Gombe Stream National Park, Tanzania. Parasitology 115: 621-627.

Nunn, C. L., Altizer, S., Jones, K. E. and Sechrest, W. 2003. Comparative tests of parasite species richness in primates. American Naturalist 162, 5: 597-614. (doi:10.1086/378721)

Paterson, S., Wilson, K. and Pemberton, J. M. 1998. Major histocompatibility complex variation associated with juvenile survival and parasite resistance in a large unmanaged ungulate population (*Ovis aries* L.). Proceedings of the National Academy of Sciences of the United States of America 95, 7: 3714-3719. (doi:10.1073/pnas.95.7.3714)

Petter, A. J., Chabaud, A. G., Delavenay, R. & Brygoo, E. R. 1972. Une nouvelle espèce de nématode du genre *Lemuricola*, parasite de *Daubentonia madagascariensis* Gmelin, et considérations sur le genre *Lemuricola*. Annales de Parasitologie Humaine et Comparée 47: 391-398.

Petter, J.-J., Albignac, R. & Rumpler, Y. 1977. Mammifères Lémuriens (Primates Prosimiens). Faune de Madagascar 44. ORSTOM-CNRS, Paris.

Phillippi, K. M. and Clarke, M. R. 1992. Survey of parasites of rhesus monkeys housed in small social groups. American Journal of Primatology 27, 4: 293-302. (doi:10.1002/ajp.1350270407)

Rabenantoandro, J., Randriatafika, F. and Lowry II, P. P. 2007. Floristic and structural characteristics of remnant littoral forest sites in the Tolagnaro area. In: Biodiversity, Ecology and Conservation of Littoral Forest Ecosystems in Southeastern Madagascar, Tolagnaro (Fort Dauphin). J. U. Ganzhorn, S. M. Goodman and M. Vincelette (eds.), pp 65-93. Smithsonian Institution, Washington D. C.

Raharivololona, B. M. 2006. Gastrointestinal parasites of *Cheirogaleus* spp. and *Microcebus murinus* in the littoral forest of Mandena, Madagascar. Lemur News 11: 31-35.

Raharivololona, B. M. 2009. L'infestation parasitaire de *Microcebus murinus* de la forêt littorale de Mandena, Madagascar. Madagascar Conservation and Development 4, 1: 52-62.

Raharivololona, B. M. and Ganzhorn, J. U. In press. Seasonality effects in gastrointestinal parasite excretion by the Gray Mouse Lemur (*Microcebus murinus*) in littoral forests of Madagascar. Endangered Species Research.

Raharivololona, B. M., Rakotondravao and Ganzhorn, J. U. 2007. Gastrointestinal parasites of small mammals in the littoral forest of Mandena. In: Biodiversity, Ecology and Conservation of Littoral Forest Ecosystems in Southeastern Madagascar, Tolagnaro (Fort Dauphin). J. U. Ganzhorn, S. M. Goodman and M. Vincelette (eds.), pp 247-258. Smithsonian Institution, Washington D. C.

Ramanamanjato, J.-B. and Ganzhorn, J. U. 2001. Effects of forest fragmentation, introduced *Rattus rattus* and the role of exotic tree plantations and secondary vegetation for the conservation of an endemic rodent and a small lemur in littoral forests of southeastern Madagascar. Animal Conservation 4, 2: 175-183. (doi:10.1017/S1367943001001202)

Randriamiadamanana, M. 1998. Contribution au Diagnostic Coprologique du Parasite *Spirocerca lupi* chez les Lémuriens du Parc Botanique et Zoologique de Tsimbazaza. Mémoire d'Ingéniorat, École Supérieure des Sciences Agronomiques, Université d'Antananarivo, Madagascar.

Rasambainarivo, F. 2008. Contribution à l'Étude des Parasites des Lémuriens en Captivité: Comparaison entre Deux Parcs Zoologiques. Thèse de doctorat, Faculté de Médecine Vétérinaire, Université d'Antananarivo, Madagascar.

Rasolofoharivelo, M. T. 2007. Human exploitation of forest resources in Mandena in 2000. In: Biodiversity, Ecology and Conservation of Littoral Forest Ecosystems in Southeastern Madagascar, Tolagnaro (Fort Dauphin). J. U. Ganzhorn, S. M. Goodman and M. Vincelette (eds.), pp 59-63. Smithsonian Institution, Washington D. C.

Schad, J., Sommer, S. and Ganzhorn, J. U. 2004. MHC variability of a small lemur in the littoral forest fragments of southeastern Madagascar. Conservation Genetics 5, 3: 299-309. (doi:10.1023/B:COGE.0000031137.50239.d3)

Schad, J., Ganzhorn, J. U. and Sommer, S. 2005. Parasite burden and constitution of major histocompatibility complex in the Malagasy mouse lemur, *Microcebus murinus*. Evolution 59, 2: 439-450. (doi:10.1554/04-312)

Schwensow, N., Fietz, J., Dausmann, K. H. and Sommer, S. 2007. Neutral versus adaptive genetic variation in parasite resistance: Importance of major histocompatibility complex supertypes in a free-ranging primate. Heredity 99: 265-277. (doi:10.1038/sj.hdy.6800993)

Schwitzer, N., Clough, D., Zahner, H., Kaumanns, W., Kappeler, P. M. and Schwitzer, C. In press. Parasite prevalence in blue-eyed black lemurs (*Eulemur flavifrons*) in differently degraded forest fragments. Endangered Species Research.

Sloss, M. W., Kemp, R. L. and Zajac, A. M. 1994. Veterinary Clinical Parasitology. Iowa State University Press, Ames.

Smith, K. F., Acevedo-Whitehouse, K. and Pedersen, A. B. 2009. The role of infectious diseases in biological conservation. Animal Conservation 12: 1-12. (doi:10.1111/j.1469-1795.2008.00228.x)

Stear, M. J., Bishop, S. C., Doligalska, M., Duncan, J. L., Holmes, P. H., Irvine, J., McCririe, L., McKellar, Q. A., Sinski, E. and Murray, M. 1995. Regulation of egg production, worm burden, worm length and worm fecundity by host responses in sheep infected with *Ostertagia circumcincta*. Parasite Immunology 17, 12: 643-652. (doi:10.1111/j.1365-3024.1995.tb01010.x)

Stoner, K. E. 1996. Prevalence and intensity of intestinal parasites in mantled howling monkeys (*Alouatta palliata*) in northeastern Costa Rica: Implications for conservation biology. Conservation Biology 10, 2: 539-546. (doi:10.1046/j.1523-1739.1996.10020539.x)

Stuart, M. D., Greenspan, L. L., Glander, K. E. and Clarke, M. R. 1990. A coprological survey of parasites of wild mantled howling monkeys, *Alouatta palliata palliata*. Journal of Wildlife Diseases 26, 4: 547-549.

Stuart, M., Pendergast, V., Rumfelt, S., Pierberg, S., Greenspan, L., Glander, K. and Clarke, M. 1998. Parasites of wild howlers (*Alouatta* spp.). International Journal of Primatology 19, 3: 493-512. (doi:10.1023/A:1020312506375)

Vincelette, M., Dumouchel, J., Giroux, J. and Heriarivo, R. 2007a. The Tolagnaro (Fort Dauphin) region: A brief overview of the geology, hydrology, and climatology. In: Biodiversity, Ecology and Conservation of Littoral Forest Ecosystems in Southeastern Madagascar, Tolagnaro (Fort Dauphin). J. U. Ganzhorn, S. M. Goodman and M. Vincelette (eds.), pp 9-17. Smithsonian Institution, Washington D. C.

Vincelette, M., Théberge, M. and Randrihasipara, L. 2007b. Evaluation of forest cover at regional and local levels in the Tolagnaro region since 1950. In: Biodiversity, Ecology and Conservation of Littoral Forest Ecosystems in Southeastern Madagascar, Tolagnaro (Fort Dauphin). J. U. Ganzhorn, S. M. Goodman and M. Vincelette (eds.), pp 49-58. Smithsonian Institution, Washington D. C.

Wallis, J. and Lee, D. R. 1999. Primate conservation: The prevention of disease transmission. International Journal of Primatology 20, 6: 803-826. (doi:10.1023/A:1020879700286)

Wright, P. C., Arrigo-Nelson, S. J., Hogg, K. L., Bannon, B., Morelli, T. L., Wyatt, J., Harivelo, A. L. and Ratelolahy, F. 2009. Habitat disturbance and seasonal fluctuations of lemur parasites in the rain forest of Ranomafana National Park, Madagascar. In Primates and their Parasites. C. Chapman and M. A. Huffman (eds.), pp 311-330. Cambridge University Press, Cambridge.

Egg numbers and fecundity traits in nine species of *Mantella* poison frogs from arid grasslands and rainforests of Madagascar (Anura: Mantellidae)

Giulia Tessa[I], Fabio Mattioli[II], Vincenzo Mercurio[III] and Franco Andreone[IV]

Correspondence:
Franco Andreone
Museo Regionale di Scienze Naturali
Via G. Giolitti 36, 10123 Torino, Italy
E-mail franco.andreone@regione.piemonte.it

ABSTRACT

The body size and number of eggs in dissected females were analysed in nine species of the Malagasy frog genus *Mantella* basing upon preserved specimens. These species were distinguished in terms of habitat and grouped as 'grassland species' (included *M. betsileo, M. expectata, M. viridis*), and 'rainforest species' (*M. baroni, M. crocea, M. cowani, M. laevigata, M. nigricans, M. pulchra*). The species with the lowest egg-number was *M. cowani* with a mean egg number of 37 ± 15, while the species with the highest egg-number was *M. viridis* with 115 ± 21 eggs. In general, the grassland species are characterised by a higher number of relatively small eggs. Moreover, their fecundity was positively and significantly correlated to female body size. Rainforest species were smaller in size and with a lower number of eggs. We interpreted these differences as possible consequences of habitat adaptations. Among the studied species, the Critically Endangered *Mantella cowani* is also featured by a low number and large size of eggs. This is likely correlated with the high elevation site of the central highlands where this species occurs.

RÉSUMÉ

Dans cet article, nous présentons des informations portant sur la taille et le nombre d'œufs de neuf espèces de grenouilles de Madagascar appartenant au genre *Mantella,* en nous basant sur l'analyse de spécimens muséologiques. Ces espèces ont été classées selon l'habitat dans lequel elles ont été récoltées en deux groupes qui sont les «*Mantella* de zones herbeuses», originaires de l'Ouest et du Sud (arides) de Madagascar (*M. betsileo, M. expectata, M. viridis*), et les '*Mantella* de forêt pluviale' (*M. baroni, M. crocea, M. cowani, M. laevigata, M. nigricans, M. pulchra*). L'espèce présentant le taux de fécondité le plus bas est *M. cowani,* avec un nombre moyen d'œufs par ponte de 37 ± 15, tandis que l'espèce avec le taux le plus élevé est *M. viridis* avec 115 ± 21 œufs par ponte. Nous avons également testé si la fécondité observée chez les espèces étudiées était différente entre le groupe des espèces de zones herbeuses (appartenant toutes au groupe *Mantella betsileo*) et celui des espèces de forêt pluviale (appartenant à plusieurs lignées phylogénétiques). Il apparaît clairement que les espèces de zones herbeuses produisent un plus grand nombre d'œufs par ponte et que les œufs sont plus grands que ceux pondus par les espèces de forêt pluviale. De plus, il existe dans le groupe des espèces de zones herbeuses une corrélation significative entre le taux de fécondité et la taille corporelle des femelles. Par contre, les résultats sont plus hétérogènes pour les espèces de forêt. Les femelles de ce groupe présentent une taille corporelle plus réduite et il n'y a pas de corrélation claire entre le nombre d'œufs et la taille corporelle des femelles. Les différences constatées ont été interprétées et expliquées par les modes de vie distincts que présentent les espèces considérées, avec la production d'un plus grand nombre d'œufs lorsque leur taille est réduite. En outre, les femelles de ces espèces présentent une taille corporelle plus importante; il a d'ailleurs été prouvé que le taux de fécondité des amphibiens est directement proportionnel à la taille des femelles. Nous pouvons formuler l'hypothèse qu'il est plus avantageux pour les *Mantella* de zones herbeuses de produire le maximum d'œufs dans un nombre limité d'événements reproductifs, qui seraient rares et localisés. Ces résultats confirment également que les *Mantella* de forêts pluviales sont probablement plus sensibles aux altérations de l'habitat, qui est plus stable que celui des espèces de zones herbeuses. Dans ce contexte, nous considérons que l'espèce *M. cowani* peut être classée comme espèce en danger critique d'extinction. Cette espèce particulière de grenouille se présente comme la plus menacée parmi les espèces de la forêt pluviale du fait qu'elle produit un nombre limité d'œufs de taille relativement importante. L'espèce est ainsi probablement plus sensible que les autres *Mantella* aux altérations environnementales et à la collecte d'individus pour le commerce d'animaux.

KEYWORDS: Amphibians, arid habitats, ecology, fecundity, Madagascar, rainforests.
MOTS CLEF : amphibiens, écologie, fécondité, forêts pluviales, Madagascar, zones herbeuses.

[I] Museo Regionale di Scienze Naturali, Via G. Giolitti, 36, 10123 Torino, Italy. Phone: +39 011 432 6306
[II] Acquario di Genova, Area Porto Antico, Ponte Spinola, 16128 Genova, Italy. Phone:+39 010 234 5210
[III] Forschungsinstitut und Naturmuseum Senckenberg, Sektion Herpetologie, Senckenberganlage 25, 60325, Frankfurt a.M., Germany. Phone: +49 691 742 8153
[IV] Phone: +39 011 432 6306

INTRODUCTION

The large island of Madagascar has more than 240 described species (Glaw and Vences 2007) and 150-200 identified but not yet described species of amphibians (Vieites et al. 2009). Of these, the genus *Mantella* is particularly striking, and it includes probably the best-known frogs of Madagascar (Vences et al. 1999a, Jovanovic et al. 2006). Almost all the 16 *Mantella* species currently known show an impressive and attractive aposematic colouration, are diurnal, accumulate toxic alkaloids in the skin (Daly et al. 1996, Vences et al. 1998, Clark et al. 2005), and are actively searched for the international pet-trade (Mattioli et al. 2006, Andreone and Randriamahazo 2008a). The *Mantella* individuals exported every year sums up to at least 30,000, and represent a large proportion of the amphibian and reptile trade of Madagascar (Rabemananjara et al. 2008). For this reason the whole *Mantella* genus is included in the CITES Appendix II, and three species (*M. cowani, M. milotympanum,* and *M. aurantiaca*) are currently classified by IUCN red list as Critically Endangered (CR), and four as Endangered (EN) (Andreone et al. 2005, 2008a,b).

One of the major tenets of the ongoing of the recently launched conservation plan for the amphibians of Madagascar (Andreone and Randriamahazo 2008b) is the constant monitoring of the species collected for the pet-trade, with regulation of the exportation quotas annually established by Malagasy authorities. In such a context, it is crucial to accumulate data on species' life history traits that may provide robust indications on their ecological sensitivity and vulnerability, supporting the decision-making process for assessing export quotas.

Among the life history traits, maximum longevity and mean fecundity are important parameters in assessing the potential extinction risks (Andreone et al. 2008a,b). Surprisingly, although several *Mantella* species are frequently raised in captivity (Andreone et al. 2006, Mattioli et al. 2006), comparatively little is known about the eggs that they lay. Within the *Mantella* species, *M. laevigata* shows the most strikingly different reproductive pattern, since females lay single large eggs in a tree-hole above the water level and parental care with egg-feeding was observed (Heying 2001). The remnant species show a more generalised reproduction mode, with egg-clutches laid on the ground outside water, next to forest streams or stagnant pools (Glaw et al. 2000, Glaw and Vences 2007). Moreover, data on egg-number provided by terrarium books (e.g., Staniszewski 2001) and websites often refer to individuals kept in captivity that are only partly comparable to those from wild populations, because conditions (e.g. temperature, humidity, feeding availability) may easily be very different to those found in nature. Thus, we are convinced that data on individuals captured in the wild are very important, and could provide useful information to unveil the species ecology.

Clearly, a further and non-negligible problem for conservation management is how to gather basic ecological information, especially considering that large number of the studies carried out on Malagasy amphibians are still focussed on the taxonomy and biodiversity assessment. This is logical, taken into account the extraordinary rate of species discoveries (Vieites et al. 2009). Given these constraints, we forecast that several years will be necessary to provide information on ecological traits for even a small fraction of the threatened species of Madagascar. Here, we strongly advocate the use of an important available reservoir of biological data, which are the preserved specimens housed in natural history museums. These vouchers can be utilised for several finalities, including studying their feeding habits, the pathogenic assessment, genetics, anatomy, reproduction, and age structure. The use of preserved museum vouchers as a source of biological data is not only useful, but also ethically relevant, since it does not involve obtaining data from live animals in the wild, and therefore maximises the amount of information that can be gathered from already dead animals (Andreone and Gavetti 2000).

In the present paper we provide original data on the egg-numbers and egg-size obtained by dissecting individuals of nine *Mantella* species. Our aim is to present not only basic information, but also to analyse the difference in traits between species inhabiting rainforest habitats and species from open environments, in order to provide useful tools for conservation management.

METHODS

We analysed nine *Mantella* species: *Mantella baroni*, *M. betsileo, M. cowani*, *M. crocea*, *M. expectata, M. laevigata*, *M. nigricans*, *M. pulchra*, and *M. viridis* (Figure 1, Table 1). Due to ongoing phylogenetic works there are some uncertainties on the taxonomic status of some of the studied species. The individuals from Isalo here attributed to *M. betsileo* (according to Crottini et al. 2008), have been considered as *M.* sp. aff.*expectata* 'South' by Glaw and Vences (2007). The individuals here attributed to *M. crocea* (according to Glaw and Vences 2007) were considered as *M.* cf. *milotympanum* by Bora et al. (2008).

The studied vouchers are currently held in the collections of Museo Regionale di Scienze Naturali, Torino (MRSN) and Parc Botanique et Zoologique de Tsimbazaza, Antananarivo (PBZT). As a standard technique, the frogs were captured in nature and euthanised by immersion in an anaesthetic solution (MS222 or chlorotone), then fixed in 4 % formalin or 90 % ethanol, and finally stored in ethanol 65 %.

The specimens come from the following localities: (1) Antoetra Plateau (Farihimazava, Vohisokina; administrative details, elevation and coordinates available in Andreone et al. 2007); (2) Antongombato area (Ambodimanga, Ambovomany, Andohenimangoko, Anketrabe, Anosiravo, Antomboko, Maleja, Mahatsinjo; Mercurio and Andreone 2008); (3) Fierenana Forest (Randrianirina 2005, Bora et al. 2008); (4) Isalo Massif (Antoha, Kazofoty, Tsitorina, Zahavola; Mercurio et al. 2008); (5) Masoala Peninsula (Ambaravato, Ambatoledama, Andasin'i Governera, Beanjada, Mahalevona, Menamalona, Nosy Mangabe; Andreone and Luiselli 2003), (6) Ranomafana (Mangevo; Vieites et al. 2009), (7) Tsaratanana Massif (Marovato; Andreone et al. 2008b), (8) Tsararano Massif (Antsarahan'ny Tsararano; Andreone and Luiselli 2000); (9) Vohimanana Forest (Vallan et al. 2004). Collectors and capture data are given in Appendix I.

Sexes were distinguished after analysis of secondary sexual characters and/or specimen dissection. As a general rule, males of the genus *Mantella* differ from females in being smaller and with more evident femoral glands (Glaw and Vences 2007). Moreover, in some species (i.e. those of the *M. betsileo* group, *M. pulchra*, and *M. crocea*) males have a horse-shoe shaped spot on the lower jaws (Glaw and Vences 2007). Totally, 96 adult females and 112 males were measured by a single person (GT) for their snout-vent length (SVL, precision at 0.1 mm). Additional

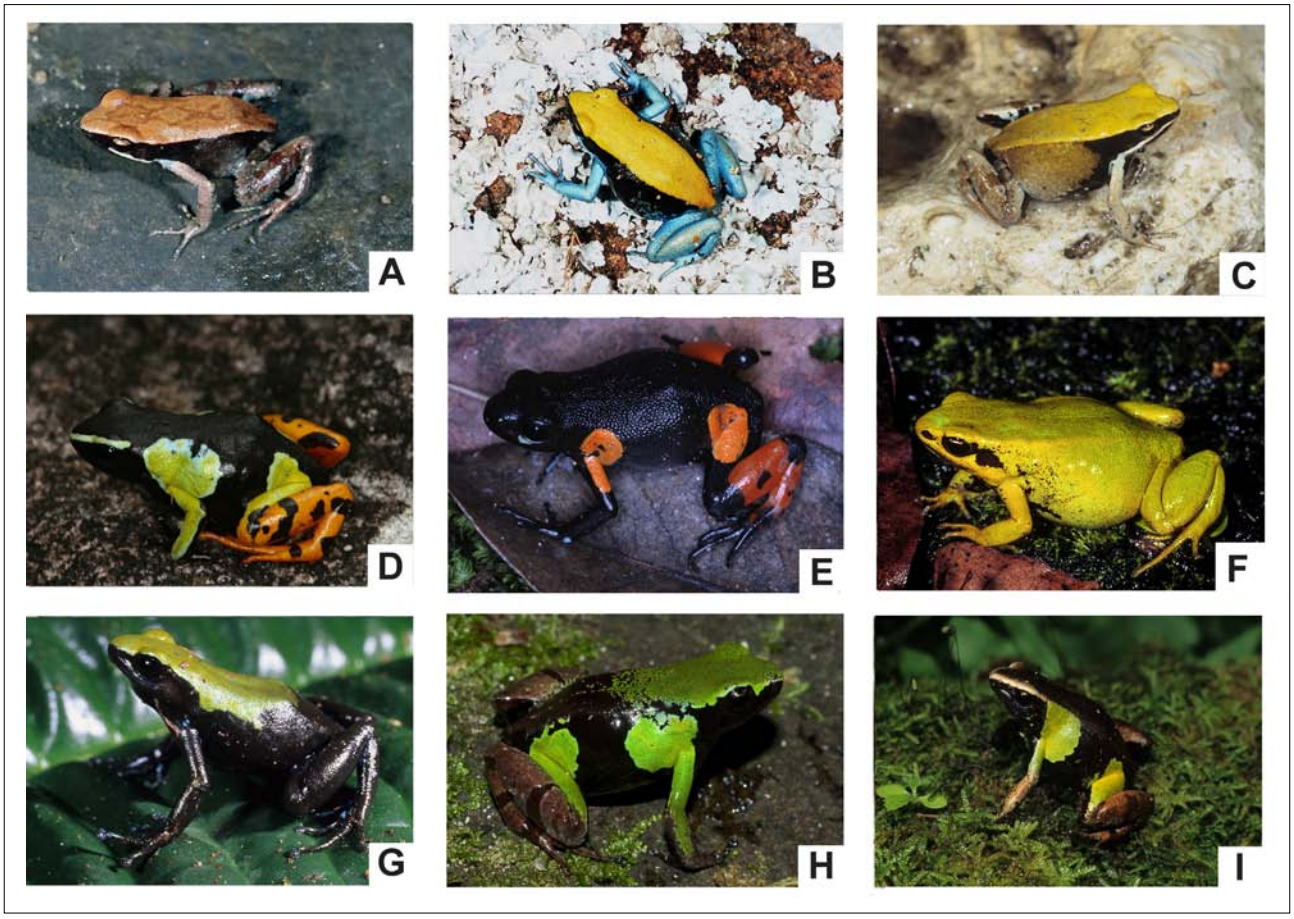


FIGURE 1. The nine *Mantella* species analysed in the paper. (A) *M. betsileo* (Isalo Massif); (B) *M. expectata* (Isalo Massif); (C) *M. viridis* (Antongombato); (D) *M. baroni,* (Antoetra); (E) *M. cowani* (Itremo); (F) *M. crocea* (captive individual without precise locality); (G) *M. laevigata* (Tsararano); (H) *M. nigricans* (Betampona); (I) *M. pulchra* (An'Ala / Vohimanana). All the photos are by F. Andreone, except for B and C (by V. Mercurio), F (by M. Vences) and H (by G. Rosa).

body size data were obtained from 29 individuals (9 females and 20 males), measured during fieldwork, but not taken as voucher specimens. Gravid females (52) were dissected by cutting longitudinally their belly. Then, ovaries were removed and mature eggs were counted under a binocular microscope.

The studied species were grouped according to their habitat preference as follows: (a) 'grassland species', with those species living in arid grasslands (Moat and Smith 2007), open habitats, and dry-deciduous forests (*M. betsileo*, *M. expectata, M. viridis*), and (b) 'rainforest species', including species from the eastern rainforest slope, mainly inhabiting rainforest and nearby areas (*M. baroni*, *M. cowani*, *M. crocea*, *M. laevigata*, *M. nigricans*, and *M. pulchra*).

Finally, we also measured the diameter (without jelly capsule) of the 20 largest mature eggs of each female. This measure is intended to give data on the mean size of mature eggs, and correlate it with the egg-number and body size.

RESULTS

Our data showed that the grassland *Mantella* species showed a relatively large SVL, ranging from *M. betsileo* (mean SVL ± SD; males = 21.22 ± 1.43 mm; females = 23.87 ± 0.87 mm), to *M. viridis* (males = 25.88 ± 2.11 mm; females = 30.35 ± 1.06 mm). The rainforest species showed a relatively higher level of SVL variability, with large-sized species like *M. cowani* (males = 25.67 ± 1.66 mm; females = 29.16 ± 0.98 mm) and *M. baroni* (males = 25.64 ± 2.40 mm; females = 28.65 ± 0.97 mm), and comparatively smaller species like *M. crocea* (males = 17.21 ± 1.11 mm; females = 20.07 ± 1.25 mm).

The pooled rainforest species were not significantly smaller (SVL = 24.44 ± 3.17 mm; mean; n = 6) than the pooled grassland species (SVL = 25.48 ± 2.80 mm; n = 3; Student's t-test: t = 0.50, p = 0.64) (Table 1). Females were larger than males in both grassland (males = 23.66 ± 2.34; females = 27.31 ± 3.26) and rainforest species (males = 23.17 ± 3.38; females = 25.71 ± 3.49). The species with the lowest egg-number was *M. cowani*, with a minimum of 20 eggs, while the species with the highest number was *M. viridis*, with a maximum of 167 eggs. The species with the smallest eggs was *M. betsileo,* with a mean diameter of 1.12 mm, and the one with the biggest eggs was *M. cowani*, with a mean diameter of 1.87 mm.

We also calculated the mean egg-number per species, and then we used these means to get a further mean for the two groups. The egg-number was higher in grassland species (88.72 ± 23.46; n = 3) than in rainforest species (45.91 ± 9.27; n = 6), although not significantly (t = 3.04; p = 0.08).

Finally, we analysed whether the relationship between egg-number and body size differed between grassland and rainforest species. We limited our comparison to species which showed non-different regression slopes: *M. viridis* and *M. expectata* (ANCOVA F = 2.302, p = 0.153) were used as representatives of grassland species, whereas *M. baroni, M. cowani* and *M. nigricans* (ANCOVA F = 1.537, p = 0.329) for rainforest species. For the other rainforest species we selected for the

TABLE1. Data on habitat, habits, snout-vent length (SVL), and fecundity in the analysed *Mantella* species. For SVL, egg number and egg diameter, table shows mean ± SD, range [minimum-maximum] and number of analysed individuals (n). The egg diameter column refers to the diameter of the 20 largest eggs selected from each dissected female.

Species	Habitat	Habits	SVL (mm)		Egg number	Egg diameter
			Males	Females		
Mantella betsileo	Grassland	Terrestrial	21.22 ± 1.43 [19.75-24.00] (11)	23.87 ± 0.87 [23.02-25.30] (4)	73 ± 18 [45-85] (4)	1.12 ± 0.19 [0.92-1.52] (80)
Mantella expectata	Grassland	Terrestrial	23.87 ± 2.53 [21.00-31.30] (17)	27.71 ± 1.80 [24.40-31.70] (14)	69 ± 17 [42-86] (5)	1.82 ± 0.10 [1.68-2.03] (100)
Mantella viridis	Grassland	Terrestrial	25.88 ± 2.11 [23.12-31.20] (20)	30.35 ± 1.06 [28.50-32.52] (31)	115 ± 21 [88-167] (11)	1.81 ± 0.09 [1.68-2.00] (220)
Mantella baroni	Rainforest	Terrestrial	25.64 ± 2.40 [18.6-28.50] (15)	28.65 ± 0.97 [26.90-30.10] (14)	42 ± 8 [53-64] (7)	1.64 ± 0.12 [1.39-1.88] (140)
Mantella cowani	Rainforest altitude grassland	Terrestrial	25.67 ± 1.66 [22.30-28.90] (14)	29.16 ± 0.98 [27.90-31.40] (15)	37 ± 15 [20-57] (3)	1.85 ± 0.22 [1.59-2.37] (60)
Mantella crocea	Rainforest	Terrestrial	17.21 ± 1.11 [14.78- 19.51] (13)	20.07 ± 1.25 [18.30-21.58] (4)	64 ± 13 [47-75] (4)	1.44 ± 0.06 [1.38-1.60] (80)
Mantella laevigata	Rainforest	Semi-arboreal	24.25 ± 0.51 [23.71-24.76] (5)	25.97 ± 1.19 [23.76-26.95] (5)	41 ± 11 [30-56] (5)	1.81 ± 0.14 [1.56-2.00] (100)
Mantella nigricans	Rainforest	Terrestrial	25.15 ± 0.86 [24.11-26.01] (5)	27.21 ± 0.60 [26.55-28.35] (7)	43 ± 12 [22-55] (7)	1.43 ± 0.15 [1.10-1.70] (140)
Mantella pulchra	Rainforest	Terrestrial	20.62 ± 2.10 [18.41-25.98] (13)	23.21 ± 1.79 [21.33-28.22] (12)	48 ± 9 [35-61] (6)	1.82 ± 0.15 [1.68-2.05] (120)

analysis the three species of the same group (*M. cowani* group) that show homogeneous characteristics. We explicitly excluded the species that had a different regression slope.

The regression slopes were significantly different between grassland and rainforest species (ANCOVA using body size as covariate, habitat as fixed factor, and egg numbers as dependent variable; $F = 26.17$, $p < 0.01$) (Figure 2). The log-transformed egg-number was positively correlated with the log-transformed female body size in grassland species (Pearson's $r^2 = 0.74$; $p < 0.01$). In rainforest species the egg-number remained rather constant in relation with the body size (Pearson's $r^2 = 0.27$; $p > 0.05$).

A linear correlation between SVL / egg diameter and egg number confirmed the different trend; the egg-size in grassland species was constant as the egg-number increased (Pearson's $r^2 = 0.00$; $p = 0.99$) whilst in rainforest species there is no correlation (Pearson's $r^2 = 0.09$; $p = 0.22$).

DISCUSSION

These are the first data on fecundity of individuals collected in nature for nine species in the genus *Mantella*. Consistent information on fecundity here presented was obtained from specimens preserved in museums, which turn out to be a suitable method.

As already done with previous studies on egg-number in other Malagasy frogs (Vences et al. 1999b), the fecundity values here presented are based on counting mature eggs. We consider this number as the best available indicator of overall fecundity, since the eggs that will be laid during the reproductive season represent it. Depending on the egg-laying strategy the number of eggs per clutch may vary among species. Species from arid areas may concentrate the egg-laying in a few occasions (coinciding with the major rainfall events), while species from rainforests lay eggs in many events. For this reason egg-counting made in captivity or in the wild may provide numbers that do not reflect the real annual fecundity. In fact, available counting of eggs within clutches of *M. betsileo* (Kuchling 1993) and *M. expectata* (Mercurio et al. 2008) are hitherto much less than data here presented (respectively 35-40 eggs versus 73 ± 18 and 69 ± 17 eggs).

This technique has some caveats to be taken in mind. In fact, specimens used for the analysis were caught in different periods of the breeding season. So far, it would have been more convenient getting fecundity data from females collected at the beginning of rainy season, just after their latency period and before they lay the eggs. However, it is virtually impossible to get an unequivocal starting date of the reproductive activity: Climatic and geographic factors such as altitude, intensity of rain and temperature make the beginning of reproductive activity highly unpredictable. Thus, even for

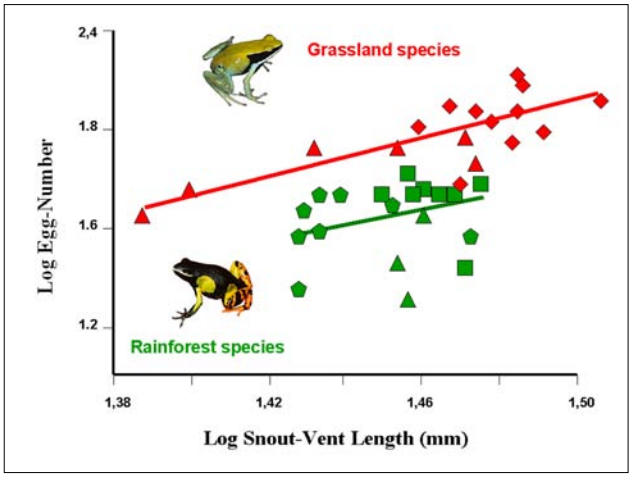


FIGURE 2. Relation between body size (SVL) and number of eggs in *Mantella* species from rainforest (red square: *M. baroni*; red triangle: *M. cowani*; red pentagon: *M. nigricans*) and grassland (green triangle: *M. expectata*; green rhombus: *M. viridis*) habitats. Rainforest species are symbolised by *M. baroni* and the grassland species by *M. viridis*.

animals captured at the beginning of the rainy season (i.e. in October), we cannot exclude that some females already laid the eggs, and/or that they have a reproductive period more extended than usually believed.

As an overall result, the grassland species had the highest number of eggs with the smallest diameter, while the rainforest species laid less and larger eggs. In two grassland species (*M. expectata* and *M. viridis*) the female body size was positively associated with the egg-number. This suggests the existence of an ongoing selection to increase female body size, associated to a higher number of eggs. This relation is already known in many species, and it is assumed that it is one of the main causes for the sexual dimorphism in anurans (Halliday and Verrell 1986). The egg-number in the three rainforest species was less variable than in grassland species, ranging 20-75 eggs, and did not show such an evident correlation between female body size and number of eggs.

Our interpretation is that there is a relationship between the egg-number and egg-size with habitat types. Grassland species lay eggs in one or a few events, likely coinciding with occasional and seasonal rains, while rainforest species lay eggs at different times of the year. The number of eggs produced by *Mantella* from arid habitats is higher, in order to maximise their reproductive efforts. Our observations support the considerations provided by Wells (2007), who argued that a high egg-number and a comparatively small egg size are often features of species living in sub-desertic and seasonal low altitude habitats, where the water is temporary.

The differences in terms of body size are likely related, and females of *Mantella* from grassland environments generally have a larger body size, which is paralleled by a higher fecundity. Moreover, we cannot exclude that a large body size in grassland species may be an adaptation against desiccation in arid environments.

Finally, we stress the importance of fecundity and habitat in terms of species conservation, especially to estimate whether the collecting of individuals for pet-trade may represent a real threat, and to establish reliable exportation quotas (Andreone et al. 2006). Our opinion is that species with a higher fecundity and a rapid growth may respond better to collection than species inhabiting stable habitats and with a slower growth. For this reason, we believe that rainforest species, which are featured by an overall lower fecundity, are likely more prone and sensitive to habitat changes and collecting need a constant conservation effort. This is in accordance with considerations provided by Andreone and Luiselli (2003). Consequently, a more continuous monitoring action is recommended, as it is stressed in the action plan designed to assure a long-term conservation of Malagasy amphibians (Andreone and Randriamahazo 2008b).

These considerations find a further support by highlighting some aspects regarding the conservation status of the Critically Endangered Harlequin mantella, *Mantella cowani* (IUCN 2008). *M. cowani* is known only from a few altitude grassland habitats and moors of Madagascar's central highland and may be considered the most threatened frog species of the island (Andreone and Randrianirina 2003, Andreone et al. 2006).

Although it is obviously difficult to ascertain what the species' original habitat was, a recent finding of the species in a high altitude rainforest located on the Itremo Massif (Birkinshaw et al. 2004) indicates that *M. cowani* could be a montane rainforest species, and most likely the current occurrence in high-altitude grasslands and along streams running in open areas is a consequence of the deforestation of Madagascar's highlands. Among this group *M. cowani* appears as the most sexually dimorphic species, with a mean body size of 25.7 ± 1.66 mm (males) and 29.2 ± 0.98 mm (females). Moreover, it shows the lowest observed mean number of eggs (37.33 ± 15.04), and the largest mean egg-size (1.85 mm) though sampling is rather limited (n=3). We suppose that the low number of voluminous eggs and the large body size observed are likely to be interpreted as traits of adaptation *M. cowani* to high altitudes, and are also features that limit the species capacity to recover in altered sites or after collection for the pet trade.

ACKNOWLEDGEMENTS

This study was done with the support from several organisations to which we are extremely grateful: ACSAM, Amphibian Specialist Group, Conservation International, EAZA, Gondwana Conservation and Research, Madagascar Fauna Group, Nando Peretti Foundation, Parc Botanique et Zoologique de Tsimbazaza, University of Antananarivo, Van Thienhoven Foundation, Wildlife Conservation Society, and World Wide Fund for Nature. We are especially indebted to the Malagasy authorities for the necessary permits and export authorisations. We thank C. Randrianantoandro for sharing with us information on the habitat of *M. cowani*, M. Vences and G. Rosa for kindly providing the photograph of *M. crocea* and *M. nigircans,* J. E. Randrianirina who accompanied us in the field, C. Angelini for fruitful discussions. J. Bielby revised the English language and L. Derussé made the French summary. Three referees and the editor greatly improved an early draft of this paper.

REFERENCES

Andreone, F. and Gavetti, E. 2000 Conservazione & Conservazione: riflessioni sul significato del collezionismo erpetologico nei musei di storia naturale. In Atti del I Congresso Nazionale della Societas Herpetological Italica (Torino, 1996). C. Giacoma (ed.), pp 29-36.Museo Regionale di Scienze Naturali. Torino, Italy.

Andreone, F. and Luiselli, L. M. 2003. Conservation priorities and potential threats influencing the hyper-diverse amphibians of Madagascar. Italian Journal of Zoology 70, 1: 53-63. (doi: 10.1080/11250000309356496)

Andreone, F. and Randriamahazo, H. 2008a. Essay 5.2. The endemic and threatened amphibians of Madagascar. In: Threatened Amphibians of the World. S. Stuart, M. Hoffmann, J. Chanson, N. Cox, R. Berridge, P. Ramani, B. Young (eds), pp 59-60. Lynx Edicions, IUCN, and Conservation International. Barcelona, Gland, Arlington.

Andreone, F., and Randriamahazo, H. 2008b. Sahonagasy Action Plan. Conservation programs for the amphibians of Madagascar / Programmes de conservation pour les amphibiens de Madagascar. Museo Regionale di Scienze Naturali, Conservation International, IUCN/SSC Amphibian Specialist Group. Turin, Italy.

Andreone, F. and Randrianirina, J. E. 2003. It's not carnival for the harlequin mantella! Urgent action needed to conserve *Mantella cowani*, an endangered frog from the High Plateau of Madagascar. Froglog 59: 1-2.

Andreone, F., Cadle, J. E., Cox, N., Glaw, F., Nussbaum, R. A., Raxworthy, C. J., Stuart, S. N., Vallan, D. and Vences, M. 2005. Species review of amphibian extinction risks in Madagascar: Conclusions from the Global Amphibian Assessment. Conservation Biology 19, 6: 1790-1802. (doi:10.1111/j.1523-1739.2005.00249.x)

Andreone, F., Mercurio, V. and Mattioli, F. 2006. Between environmental degradation and international pet trade: Conservation strategies for the threatened amphibians of Madagascar. Natura – Società italiana di Scienze naturali e Museo civico di Storia Naturale di Milano, 95, 2: .81-96.

Andreone, F., Vences, M., Glaw, F. and Randrianirina, J. E. 2007. Remarkable records of amphibians and reptiles on Madagascar's central high plateau. Tropical Zoology 20, 1: 19-39.

Andreone, F., Carpenter, A. I., Cox, N., du Preez, L., Freeman, K., Furrer, S., Garcia, G., Glaw, F., Glos, J., Knox, D., Köhler, J., Mendelson III, J. R., Mercurio, V., Mittermeier, R. A., Moore, R. D. Rabibisoa, N. H. C., Randriamahazo, H., Randrianasolo, H., Rasoamampionona Raminosoa, N., Ravoahangimalala Ramilijaona, O., Raxworthy, C. J., Vallan, D., Vences, M., Vieites, D. R. and Weldon, C. 2008a. The challenge of conserving amphibian megadiversity in Madagascar. PLoS Biology 6, 5: e118. (doi:10.1371/journal.pbio.0060118)

Andreone, F., Cox, N. A., Glaw, F., Köhler, J., Rabibisoa, N. H. C., Randriamahazo, H., Randrianasolo, H., Raxworthy, C. J., Stuart, S. N., Vallan, D. and Vences, M. 2008b. Update of the Global Amphibian Assessment for Madagascar in light of species discoveries, nomenclature changes, and new field information. Malagasy poison frogs in the pet trade: A survey of levels of exploitation of species in the genus Mantella. In: A Conservation Strategy for the Amphibians of Madagascar. F. Andreone (ed.), pp 419-438. Monografie 45. Museo Regionale di Scienze Naturali, Torino.

Andreone, F., Glaw, F., Mattioli, F., Jesu, R., Schimmenti, G., Randrianirina, J. E. and Vences, M. 2009. The peculiar herpetofauna of some Tsaratanana rainforests and its affinities with Manongarivo and other massifs and forests of northern Madagascar. Italian Journal of Zoology 76, 1: 92-110. (doi: 10.1080/11250000802088603)

Birkinshaw, C., Andriamihajarivo, T. H., Randrianaina, L., Randrianarivelo, C., Rasolondraibe, B., Andriamandrato, R. & Razafindrasoa, R. 2004. Evaluation bio-écologique des ressources naturelles et pression anthropiques - études socio-économiques en vue d'établir une proposition de stratégie de conservation pour le Massif d'Itremo. Unpublished Report, the Missouri Botanical Garden, Antananarivo.

Bora, P., Dolch R., Jenkins R., Jovanovic O., Rabemananjara, F. C. E., Randrianirina J., Rafanomezantsoa, J., Raharivololoniaina, L., Ramilijaona O., Raminosoa N., Randrianavelona R., Raselimanana A., Razafimahatratra B., Razafindraibe T. and Vences M. 2008. Geographical distribution of three species of Malagasy poison frogs of high conservation priority: *Mantella aurantiaca*, *M. crocea* and *M. milotympanum*. Herpetology Notes 1: 39-48.

Clark V. C, Raxworthy, C. J, Rakotomalala, V., Sierwald, P. and Fisher, B. L. 2005. Convergent evolution of chemical defense in poison frogs and arthropod prey between Madagascar and the Neotropics. Proceedings of the National Academy of Sciences of the United States of America 102, 33: 11617-11622.

Crottini, A., Chiari, Y., Mercurio, V., Meyer, A., Vences, M. and Andreone, F. 2008. Into the canyons: The phylogeography of the Malagasy frogs *Mantella expectata* and *Scaphiophryne gottlebei* in the arid Isalo Massif, and its significance for conservation (Amphibia: Mantellidae and Microhylidae). Organisms Diversity & Evolution 8, 5: 368–377. (doi:10.1016/j.ode.2008.08.001)

Daly, J. W., Andriamaharavo, N. R., Andriantsiferana, and Myers, C. W. 1996. Madagascan poison frogs (*Mantella*) and their skin alkaloids. American Museum Novitates 3177: 1-34.

Glaw, F. and Vences, M. 2007. A Fieldguide to the Amphibians and Reptiles of Madagascar. Third edition. Vences & Glaw Verlag, Cologne.

Glaw, F., Schmidt, K., & Vences, M. 2000. Nachzucht, Juvenilfärbung und Oophagie von *Mantella laevigata* im Vergleich zu anderen Arten der Gattung (Amphibia: Ranidae). Salamandra, 36: 1-24.

Halliday, T. R. and Verrell, P. A. 1986. Sexual selection and body size in amphibians. Herpetological Journal 1, 3: 86-92.

Heying, H. E. 2001. Social and reproductive behaviour in the Madagascan poison frog, *Mantella laevigata*, with comparison to the dendrobatids. Animal Behaviour 61: 567-577. (doi: 10.1006/anbe.2000.1642)

IUCN. 2008. 2008 IUCN Red List of Threatened Species. <www.iucnredlist.org> Accessed 19 May 2009.

Jovanovic, O., Rabemananjara, F., Ramilijaona, O., Andreone, F., Glaw, F. and Vences, M. 2006. Frogs of Madagascar Genus *Mantella*. Pocket Identification Guide. Conservation International, Washington.

Kuchling, G. 1993. Zur Verbreitung und Fortpflanzung von *Mantella betsileo* in Westmadagaskar. Salamandra 29, 3-4: 273-276.

Mattioli, F., Gili, C. and Andreone, F. 2006. Economics of captive breeding applied to the conservation of selected amphibian and reptile species from Madagascar. Natura – Società italiana di Scienze naturali e Museo civico di Storia Naturale di Milano 95 (2): 67-80.

Mercurio, V. and Andreone, F., 2008. New distribution data of the green mantella, *Mantella viridis*, from northern Madagascar (Anura: Mantellidae). Herpetology notes, 1: 3-7

Mercurio, V., Aprea, G., Crottini, A., Mattioli, F., Randrianirina, J. E., Razafindrabe, T. J. and Andreone, F. 2008. The amphibians of Isalo Massif, southern-central Madagascar: High frog diversity in an apparently hostile dry habitat. In: A Conservation Strategy for the Amphibians of Madagascar. F. Andreone (ed.), pp 143–196. Monografia del Museo Regionale di Scienze Naturali 45, Torino.

Moat, J. and Smith, P. 2007. Atlas of the Vegetation of Madagascar. Kew Publishing, Royal Botanic Gardens, Kew.

Rabemananjara, F. C. E., Rasoamampionona Raminosoa, N., Ravohangimalala Ramilijaona, O., Andreone F., Bora, P., Carpenter, A. I., Glaw, F., Razafindrabe, T. J., Vallan, D., Vieites, D.R. and Vences, M. 2008. Malagasy poison frogs in the pet trade: A survey of levels of exploitation of species in the genus *Mantella*. In: A Conservation Strategy for the Amphibians of Madagascar. F. Andreone (ed.), pp 277–300. Monografia del Museo Regionale di Scienze Naturali 45, Torino.

Randrianirina, J. E. 2005. Nouvelles données sur la distribution d'une espèce de grenouille menacée dans la foret de Fierenana, Madagascar, *Mantella milotympanum* (Amphibia, Mantellidae). Bulletin de la Societé Herpetologique de France 115: 48-54.

Staniszewski, M. 2001. Mantellas. Edition Chimaira, Frankfurt am Main.

Vallan, D., Andreone, F., Raherisoa, V. H. and Dolch, R. 2004. Effects of low, selective wood exploitation on amphibians in a tropical rain forest in east Madagascar. Oryx 38, 4: 410-417. (doi:10.1017/S003060530400078X)

Vences, M., Glaw, F. and Böhme, W. 1998. Evolutionary correlates of microphagy in alkaloid-containing frogs (Amphibia: Anura). Zoologischer Anzeiger 236, 4: 217-230.

Vences, M., Glaw, F. and Böhme, W., 1999a. A review of the genus *Mantella* (Anura, Ranidae, Mantellinae): Taxonomy, distribution and conservation of Malagasy poison frogs. Alytes 17, 1-2: 3-72.

Vences, M., Glaw, F. and Zapp, C. 1999b. Bemerkungen zu Eizahlen und Eigrößen bei madagassischen Fröschen der Gattungen Tomopterna, *Aglyptodactylus*, *Boophis* und *Mantidactylus* (Amphibia: Ranidae). Salamandra 35, 2: 77-82.

Vieites, D. R., Wollenberg, K.C., Andreone, F., Köhler, J., Glaw, F., and Vences, M. 2009. Vast underestimation of Madagascar's biodiversity evidenced by an integrative amphibian inventory. Proceedings of the National Academy of Sciences of the United States of America 106, 20: 8267-8272. (doi: 10.1073/pnas.0810821106)

Wells, K. D. 2007. The ecology and behavior of amphibians. The University of Chicago Press, Chicago.

APPENDIX

APPENDIX I

Specimens examined (MRSN = specimens housed in the Museo Regionale di Scienze Naturali, Torino; PBZT = specimens housed in the Parc Botanique et Zoologique de Tsimbazaza, Antananarivo). Abbreviations: FA = F. Andreone; VM = V. Mercurio; JER = J. E. Randrianirina; Prov. = Province; IM = Isalo Massif; MP = Masoala Peninsula, AA = surroundings of Antongombato and Montagne des Français.

Mantella baroni - MRSN A2404, no precise locality data, I.2000; MRSN A2900 (Mangevo, Ranomafana, Fianarantsoa Prov., 10.II.1994, FA and VM), MRSN A2903 (Mangevo, Ranomafana, Fianarantsoa Prov., 10.II.1994, FA and VM), MRSN A2915 (no data), MRSN A2985 (Mahalevona, MP, Antsiranana Prov., 17.II.2002, JER); PBZT 739, no località data, I.2000; *Mantella betsileo* - MRSN A5231 (Tsitorina, IM, Fianarantsoa Prov., 3.XII.2004), MRSN A5238 (Tsitorina, IM, Fianarantsoa Prov., 3.XII.2004); MRSN A5232 (Antoha, IM, Fianarantsoa Prov., 3.XII.2004); MRSN A5239 (Kazofoty, IM, Fianarantsoa Prov., 2.XII.2004); *Mantella cowani* - MRSN A3203 (Farimazava, Antoetra, Fianarantsoa Prov., 31.I.2003, FA), MRSN A3206 (Farimazava, Antoetra, Fianarantsoa Prov., 31.I.2003, FA); MRSN A3208 (Vohisokina, Antoetra, Fianarantsoa Prov., 28.I.2003, FA); *Mantella crocea* - PBZT unlabelled, likely Fierenana; *Mantella expectata* - MRSN A5156 (Zahavola, IM, Fianarantsoa Prov., 24.XI.2004), MRSN A5168 (Zahavola, IM, Fianarantsoa Prov., 16.XI.2004), MRSN A5172 (Zahavola, IM, Fianarantsoa Prov., 16.XI.2004), MRSN A5180 (Zahavola, IM, Fianarantsoa Prov., 12.XI.2004), MRSN A5206 (Zahavola, IM, Fianarantsoa Prov., 24.XI.2004); *Mantella laevigata* - MRSN A2999 (Beanjada, MP, Mahalevona, Antsiranana Prov., 22.XI.1998); MRSN A3000 (Andasin'i Governera, MP, Mahalevona, Antsiranana Prov., 6.XII.1998); MRSN A4475 (Ambaravato, MP, Mahalevona, Antsiranana Prov., 4.XII.1999, FA); MRSN A4482 (Menamalona, MP, Mahalevona, Antsiranana Prov., 11.XII.1999, FA), MRSN A4505 (Menamalona, MP, Mahalevona, Antsiranana Prov., 11.XII.1999); MRSN A4506 (Menamalona, MP, Mahalevona, Antsiranana Prov., 11.IX.1999); *Mantella nigricans* – MRSN A4454 (Ambatoledama, MP, Mahalevona, Antsiranana Prov., 16.XI.1998); MRSN A4456 (Beanjada, MP, Mahalevona, Antsiranana Prov., 22.XI.1998, FA); MRSN A4484 (Marovato, Tsaratanana, Antsiranana Prov., 28.XII.2000, JER); MRSN A4526 (Nosy Mangabe, Maroantsetra, Toamasina Prov., 1.VI.1997, FA) MRSN A4528 (Antsarahan'ny Tsararano, Tsararano, Antsiranana Prov., 29.XI.1996), MRSN A4529 (Antsarahan'ny Tsararano, Tsararano, Antsiranana Prov., 29.XI.1996); *Mantella pulchra* - PBZT unlabeled (Fierenana, Toamasina Prov., I.2004); *Mantella viridis* – MRSN A5050 (Antomboko, AA, Antsiranana Prov., 21.I.05); MRSN A5055 (Ambovomany, AA, Antsiranana Prov., 15.I.2005); MRSN A5066 (Anosiravo, AA, Antsiranana Prov., 24.I.2005); MRSN A5088 (Antomboko, AA, Antsiranana Prov., 6.I.2005); MRSN A5090 (Anketrabe, AA, Antsiranana Prov., 5.I.2005); MRSN A5095 (Andohenimangoko, AA, Antsiranana Prov., 8.I.05); MRSN A5102 (Ambodimanga, AA, Antsiranana Prov., 17.I.2005); MRSN A5114 (Maleja, AA, Antsiranana Prov., 7.I.2005), MRSN AA5127 (Maleja, AA, Antsiranana Prov., 7.I.2005); MRSN A5117 (Andohenimangoko, AA, Antsiranana Prov., 15.I.2005); MRSN A5121 (Mahatsinjo, AA, Antsiranana Prov., 17.I.2005)

The significance of human induced and natural erosion features (lavakas) on the central highlands of Madagascar

Michael S. Zavada, Yeqiao Wang[I],
Gérard Rambolamanana[II], Andriamiranto Raveloson[II]
and Hélène Razanatsoa[III]

Correspondence:
Michael S. Zavada
East Tennessee State University, Department of Biological Sciences, Box 70703, Johnson City, TN 37615, USA
E-mail: zavadam@etsu.edu

ABSTRACT

Massive hill slope erosion in Madagascar is represented by the widespread gullies called 'lavaka'. Lavakas may be result of natural processes that involves a combination of continuous tectonic uplift that maintains a high angle of repose, ground water sapping at the soil-saprolite interface, and subsequent collapse of the soil surface due to low grade seismic activity in the central highlands. Forest cover ranges between 25-45% in the study area and is primarily restricted to riparian and lavaka habitats. Development of forest cover associated with riparian and lavaka habitats may be due to increased soil moisture, exposure of a less nutrient poor saprolite and/or soil compaction. In addition, riparian and lavaka habitats harbor a significantly higher diversity of plant species than the surrounding grasslands. Lavakas may be a result of natural processes and may play a role in the development of Madagascar's landscape evolution.

RÉSUMÉ

Les formes d'érosion connues sous le terme de lavakas peuvent être le résultat d'un processus naturel impliquant à la fois un soulèvement tectonique continu qui maintient un angle de repos important, un processus de sape des eaux souterraines à l'interface sol – saprolite et un effondrement consécutif de la surface du sol du à la faible activité sismique des hautes terres du centre. Ce phénomène est suivi d'une succession géomorphologique à long terme et d'une succession de végétation liées aux lavakas, de sorte que les lavakas et la végétation qu'ils abritent sont isolés du bassin versant principal. Les rivières et les bassins versants en tant qu'éléments séparateurs ont, semble-t-il, joué un rôle dans la richesse de la biodiversité de Madagascar. La présente étude montre que la végétation associée aux forêts riveraines et aux lavakas représente 25-45% de la couverture forestière des hautes terres du centre. L'absence de forêts sur les zones herbeuses voisines ou la présence d'une succession de végétation liée aux zones herbeuses suggère que le développement de la végétation arborée pourrait être lié à des changements du degré d'humidité du sol, de la disponibilité des éléments nutritifs ou du tassement du sol. Le taux d'humidité s'est avéré être constant dans tous les habitats échantillonnés. La disponibilité en éléments nutritifs peut jouer un rôle dans la structure de la végétation. Les lavakas se formant par l'effondrement du sol superficiel par un processus de sape des eaux souterraines à l'interface sol – saprolite, la zone racinaire de la végétation se trouve alors à proximité des saprolites pauvres en éléments nutritifs. Le degré de tassement du sol diffère de manière significative entre les forêts ripicoles/lavakas et les zones herbeuses. Les zones herbeuses ont montré des mesures de résistance du sol au pénétromètre élevées (moyenne de 17,9) et un profil de tassement qui peut limiter le développement racinaire d'un certain nombre d'espèces. Les mesures effectuées dans les forêts riveraines et les lavakas étaient respectivement de 14,0 et 9,7 qui sont des valeurs compatibles avec un développement racinaire. De ce fait, les différences entre les structures de la végétation et la diversité peuvent trouver leur origine dans la capacité des plantes à développer leur système racinaire. Il existe également un rapport inverse entre la diversité spécifique et le degré de tassement du sol dans les trois habitats. La mobilité des sols dans les lavakas et les habitats ripicoles peut réduire le tassement en surface et juste en dessous en favorisant ainsi un labourage naturel. Les lavakas peuvent ainsi être le résultat d'un processus naturel et jouer un rôle important dans le développement de l'évolution des paysages de Madagascar et de la biodiversité.

KEYWORDS: Madagascar, lavaka, landscape evolution, geomorphology, riverine forest.
MOTS CLEF : Madagascar, lavaka, évolution des paysages, géomorphologie, forêt riveraine.

INTRODUCTION

International aid and development agencies have designated Madagascar's erosion rate the highest in the world (e.g., World Bank/USAID/Cooperation Suisse/UNESCO/UNDP/WWF 1986, United States Agency International Development (USAID) 1998). Annual erosion rates are estimated at 200-400 tons / ha, 20-40 times above the world average (Enquêtes Prioritaires auprès des Ménages 1999). Massive hill slope erosion is represented by the extraordinary and widespread gullies called 'lavaka' (Tricart 1953) from the Malagasy word for 'hole'. Heavy sediment

[I] University of Rhode Island, Department of Natural Resources Science, Kingston, RI 02881, USA. Phone: 401 874 4345.
[II] Institute & Geophysical Observatory, B/P 3843, 101 Antananarivo, Madagascar. Phone: +261 2022 25353.
[III] Flora Department, B/P 4096, PBZT, Tzimbazaza, 101 Antananarivo, Madagascar. Phone: +261 2022 31149.

loading in rivers, attributed to lavaka formation, is described as the "land bleeding into the sea" (Helfert and Wood 1986). The problems caused by erosion in Madagascar are legion. High sediment loads cause rapid siltation in estuaries, lavaka formation destroys agricultural land and collapses roads, and sediment gravity flows issuing from active lavakas swamp tilled fields, ruining crops. It is asserted that "man is essentially to blame" (Randrianarijaona 1983) for erosion as a result of overgrazing, grassland burning, deforestation, and cart track formation (Tricart 1953, Riquier 1954, Petit and Bourgeat 1966, Hurault 1971, Hoeblich and Hoeblich 1983, Andriamampianina 1985, Gade 1996). International aid organizations describe the erosion as emblematic of human-caused environmental degradation and part of the overall threat to the ecology and biodiversity of Madagascar (e.g., USAID 2000, 2002).

The role of humans as the cause of deforestation is engrained as conventional wisdom, and has its origins rooted in the French colonial pre-conceived notions of human impact on the Malagasy landscape (Kull 2000). It is asserted that the central highlands were deforested by human activity over the last 2000 years (Klein 2002 and references therein). It is also asserted that the erosion features (lavakas) in the central highlands are a result of overgrazing, and that the deforestation on the central highlands represents one of the most severely affected habitats not only in Madagascar but the world (Wells and Andriamihaja 1993, Kull 2000, Klein 2002). The abundance of lavakas in the highlands and the large suspended load of Malagasy rivers during the wet season are often cited as a testament to deforestation and related erosion in the central highlands (Randrianarijaona 1983, Helfert and Wood 1986). There are, in fact, few or no data on erosion rates or bulk sediment transport rates, and so these assertions are unsubstantiated. Gradual data acquisition in the last 20 years reveals that the story of landscape evolution in Madagascar is not simple, and that the role of humans is less clear. Palynological investigations of lake cores that span the Holocene suggest that patchy forest interspersed with grassland was characteristic of the central highlands prior to the arrival of the first humans (Burney 1987abc, 1988). Charcoal is also found in the portion of the stratigraphic section that pre-dates the arrival of humans. This suggests that the grassland was maintained by the natural occurrence of fire (MacPhee et al. 1985, Burney 1987abc, 1988), and that the central highlands may not have been deforested by human activity (Kull 2000, Klein 2002). The population of the central highlands may be using fire to maintain a habitat that was already present when their ancestors first arrived in Madagascar.

The role of humans in lavaka formation and massive erosion is also in question. Only 25% of lavakas studied have been directly linked to human activity, whereas about 20% have clear non-anthropogenic causes (Wells and Andriamihaja 1993). Both the proximal and ultimate causes of most lavakas studied remain undetermined (Wells and Andriamihaja 1993). Human activities may well exacerbate erosion and lavaka formation (Tricart 1953, Riquier 1954, Petit and Bourgeat 1966, Wells and Andriamihaja 1993, 1997, Raharijaona-Raharison and Randrianarison 1999, Cox et al. 2003, 2004), but there is evidence that lavakas pre-date the 2,000-year human occupation of Madagascar (Bourgeat and Ratsimbazafy 1975, Hoeblich and Hoeblich 1983, Wells and Andriamihaja 1993, 1997, Cox et al. 2009).

Wells et al. (1991) and Wells and Andriamihaja (1993, 1997) proposed a series of five phases to describe the formation of lavakas. Type I lavaka are initiated mid-slope and are identified by the amphitheater-like steep walls of the incipient lavaka as a result of the in situ collapse of a soil surface. The collapse of the soil surface in the Type I lavaka is different from mass wasting because the intact soil surface of the lavaka is displaced downward, in contrast to the flow and mixing of the soil parallel to the angle of the slope that generally takes place in a mass wasting event. The Madagascar highlands has undergone Neogene to Holocene uplift (Pique et al. 1999, de Wit 2003), this has generated steep terrain with a thin lateritic soil which rests on a saprolitic mantle 10s of meters thick. Cox et al. (2004) have proposed this is due to groundwater sapping. The sapping is initiated at the beginning of the wet season via deep fissures or cracks in the soil, which form naturally during the dry season (soils during the dry season hold less than 5% moisture), or may be caused by animal or human footpaths. These fissures or cracks provide a direct avenue of ingress to the soil-saprolite interface. The sapping creates underground caverns at this interface and is followed by the collapse of the soil surface and the initial formation of the lavaka.

After Type I lavaka formation, a Type II lavaka forms a drainage incisions at the lowest down slope point of the lavaka, from which the underlying and surficial soils erode into the existing drainage basins. Sediment volumes on the order of 8,000 m^3 occur in a few months and are responsible for the high bed loads observed in Malagasy rivers (Cox et al. 2003, 2004, 2009). During this phase high erosion rates strip the nutrient poor laterites down to the in situ saprolite providing a nutrient rich island of weathered saprolite that will subsequently support forest development.

Type III and IV lavakas show some peneplanation of the steep walls and the interior lavaka soils that were initially formed. Type III and IV lavaka are often identified by the well-developed vegetation in the lavaka.

The Type V lavaka show further peneplanation of the bowl shaped feature, which is accompanied by soil nutrient depletion due to extended leaching, and the eventual degradation of the in situ forest and the re-invasion of the grassland.

The purpose of this investigation is to examine, a) the forest cover in the central highlands, b) the spatial configuration of the forest cover and c) the role the natural occurring erosion features may play in the development of landscape evolution and vegetation patterning on the central highlands in Madagascar.

METHODS

SATELLITE DATA. Landsat Enhanced Thematic Mapper Plus (ETM+) remote sensing data was acquired from 19 April 2003 for characterization of the landscape. ETM+ data have a 30-meter spatial resolution and seven spectral bands ranging from the visible to the thermal infrared portion of the spectrum. A subset of the pseudo-color image illustrates the spatial pattern of vegetation in the study area. We geo-referenced the image data to Universal Transverse Mercator (UTM) map coordinates.

LAND COVER CLASSIFICATION. We conducted GPS guided fieldwork to ground truth the geo-referenced training sites. The documented reference sites provided guidance for our interpretation of the classification of ETM+ image. We sampled localities at approximately 10 km intervals that included repre-

sentative grassland, lavakas in various stages of succession and riparian forests in the vicinity of Madagascar Route Nationale (RN) 4 from Maevatanana to Mahatsinjo (Figure 1). During the field work, we recorded GPS points in UTM coordinates for each site with attribute descriptions and digital photographs. We then converted the UTM coordinates into a GIS point file using ESRI ArcGIS. The GIS data were on the ETM+ image so that the field sites and the attributes could be further examined to assist image classification and verification. As the landscape pattern is rather simple, we employed unsupervised classification on the ETM+ data for several sample sites to extract spectral signatures to use as training sites for classifying the entire image. Upon finishing the classification, we labeled the spectral clusters into general categories of lavaka, riparian, and grassland habitats and water.

SAMPLE SITE CHARACTERISTICS. We documented soil characteristics including color using the Munsell Soil Color Chart, pH, moisture content, soil compaction with a Lang penetrometer, and the angle of repose for each sample sites. We determined the number of plant taxa at each locality and used an analysis of variance to determine if species diversity was significantly different among the three habitats (Table 1). We also converted the known seismic epicenters for earthquakes that occurred between 1988 and 2004 into a GIS point file so that the possible seismic effects on the formation of erosion features could be observed through remote sensing data (Figure 1).

RESULTS

Many lavakas exhibit features indicative of ephemeral erosion features. In the present study we examined satellite data from the early 1980s, early 1990s and the data presented in this paper is from April 2003. We were unable to identify, using these data, the formation of new lavakas in our study region during this 20-25 year interval. This unexpected observation raises an important question regarding lavaka longevity. We assumed their age was at least as old as the oldest trees found in many of the Type III and IV lavakas. Cox et al. (2004, 2009), based on C^{14}-dates of sub-fossil plant material in deposits of the lavakas, suggest that the time frame for the growth and development of Type I-V lavakas may be in the thousands of years. This is supported by the low recruitment of new erosional features spanning a 30-50 year photographic history in Cox's study area of the central highlands (Cox et al. 2009), and our own studies using satellite data from the early 1980s.

In the study region, three areas (A, B, C) were chosen to determine the percentage of forest cover (Figure 2A-D). Classified Landsat ETM+ revealed the landscape characteristics of the study region (Figure 2A-D) and allowed us to determine the area covered by water, grassland and lavaka forest and riparian vegetation (Table 2). Forest cover for study area A (Figures 2A, B, 3A-C, Appendix 2A, C, E), study area B (Figure 2A, C) and study area C (Figure 2A, D) are given in Table 2. The total area of each site is 93,636 ha.

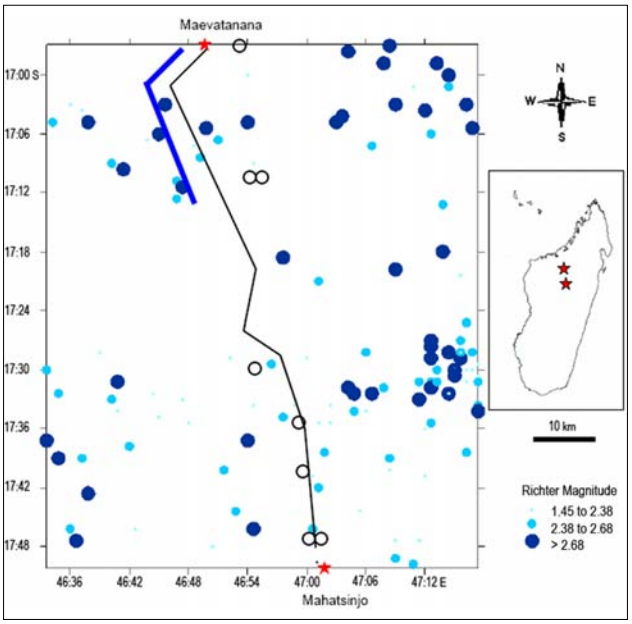


FIGURE 1. Map showing location of the study region and the RN4 (thin black line), which served as a sampling line in the study area. The distribution of the epicenters of earthquakes and their magnitude are indicated in blue. The sampled lavakas are indicated by open circles; note that the high frequency of lavakas are in the most seismically active areas. The thick blue line is the location of the Betsiboka River.

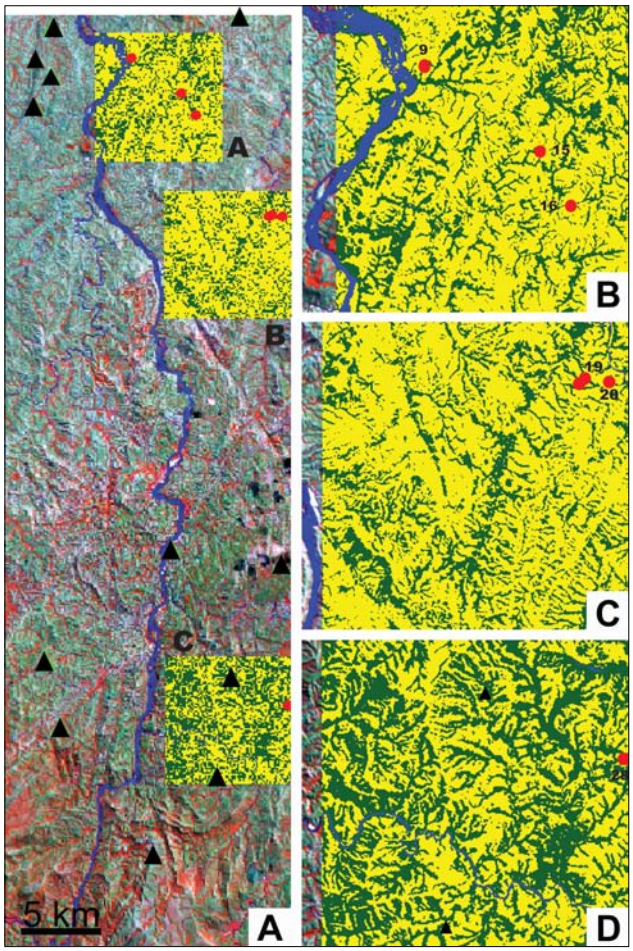


FIGURE 2A. The satellite image of the study region with the three areas A, B, and C showing the grassland (yellow), lavaka and riparian forest (green), and water (blue). Study area A corresponds to Figure 2B, area B corresponds to Figure 2C and area C corresponds to Figure 2D. The triangles show the epicenters of earthquakes over the past 25 years in this study of 3.0 Richter Magnitude or greater. Red dots are representative sample localities.
FIGURE 2B. Study area A showing the distribution of grassland (yellow), lavaka and riparian forest (green) and water (blue). Site 9 = Appendix 2A, Sample Site 15 = Appendix 2C, and Sample Site 16 = Appendix 2E. The upper left hand corner of the figure has Longitude and Latitude coordinates of E 046° 49′ 02.0″ S 17° 09′ 44.6″.
FIGURE 2C. Study area B showing the distribution of grassland, lavaka and riparian forest and water. Sample Site 19 = Appendix 2B, Sample Site 20 = Appendix 2D. The upper left hand corner of the figure has Longitude and Latitude coordinates of E 046° 51′ 47.9″ S 17° 15′ 35.8″.
FIGURE 2D. Study area C showing the distribution of grassland, lavaka and riparian forest and water. Sample Site 28 = Appendix 2F. The upper left hand corner of the figure has Longitude and Latitude coordinates of E 046° 52′ 00.7″ S 17° 32′ 40.3″.

TABLE 1. Data collected at 35 ground-truthed sites in the study area, showing habitat type, longitude and latitude (degrees minutes seconds), elevation, Munsell soil color, the average of three readings taken with a Lang Penetrometer to describe compaction properties of the soil, soil moisture, pH, the angle of repose and the number of identified plant taxa at each locality.

Site	Habitat	Coordinates	Elevation (m)	Munsell Soil Color	Lang Penetrometer (average of 3 readings)	Soil Moisture Content	pH	Angle of Repose	Number of species present
1	Grassland	E046° 46' 34.3" S17° 01' 01.5"	85			<5 %			3
2	Grassland	E046° 46' 50.6" S17° 00' 59.7"	105	2.5YR 4/6	18	<5 %	6.9	5	2
3	Grassland	E046° 48' 19.8" S17° 00' 43.1"	128			<5 %			4
4	Riparian Forest	E046° 48' 48.1" S17° 02' 43.8"	158	2.5YR 3/0	5.8	40 %	6.9		16
5	Riparian Forest	E046° 48' 10.1" S17° 04' 02.9"	147						7
6	Grassland	E046° 48' 37.2" S17° 04' 58.1"	214	10YR 6/6	15.5	<5 %	6.9	0	3
7	Riparian Forest	E046° 49' 18.3" S17° 08' 15.9"	266	2.5YR 5/4	9	<5 %	6.9	40	12
8	Riparian Forest	E046° 50' 33.1" S17° 10' 43.9"	269	2.5YR 5/2	9.5	<5 %		43	19
9	Grassland	E046° 50' 32.5" S17° 10' 41.3"	263	2.5YR 5/2	19	<5 %	6.9		4
10	Grassland	E046° 48' 37.2" S16° 59' 57.4"	131			<5 %			2
11	Riparian Forest	E046° 48' 56.8" S16° 59' 04.3"	82						3
12	Grassland	E046° 51' 13.9" S16° 57' 02.5"	78			<5 %			3
13	Lavaka	E046° 55' 19.4" S16° 57' 36.8"	142	2.5YR 5/4	14	<5 %	6.6	47	15
14	Grassland	E046° 55' 19.9" S16° 57' 38.3"	218	2.5YR 5/6	17.5	<5%	6.2	0	8
15	Grassland	E046° 52' 28.1" S17° 11' 58.9"	353			<5 %			2
16	Riparian Forest	E046° 52' 59.7" S17° 12' 48.3"	306						1
17	Lavaka	E046° 55' 53.3" S17° 16' 32.1"	396			<5 %			10
18	Grassland	E046° 55' 53.6" S17° 16' 31.5"	403	2.5YR 5/4	18.5	<5 %	6.8	47	3
19	Lavaka	E046° 55' 58.8" S17° 16' 26.9"	409			<5 %			4
20	Riparian Forest	E046° 56' 22.3" S17° 16' 30.1"	361	2.5YR 5/6	11.4	<5 %		35	13
21	Riparian Forest	E046° 57' 29.0" S17° 27' 01.5"	576						9
22	Grassland	E046° 59' 48.1" S17° 28' 43.1"	607						3
23	Grassland	E046° 58' 43.9" S17° 29' 43.6"	620	2.5YR 4/6	18	<5 %	6.6		2
24	Grassland	E046° 57' 50.1" S17° 32' 58.3"	685	2.5YR 5/6	18	<5 %	6.9	47	2
25	Riparian Forest	E046° 57' 55.4" S17° 32' 56.1"	694	2.5YR 5/6	13	<5 %	6.5		15
26	Lavaka	E046° 57' 26.4" S17° 33' 38.7"	719					47	9
27	Grassland	E046° 56' 48.7" S17° 34' 34.6"	698						3
28	Riparian Forest	E046° 56' 50.1" S17° 34' 34.1"	699						15
29	Grassland	E046° 57' 29.6" S17° 38' 06.5"	661	2.5YR 5/6	18.5	<5 %	6.8	5	2
30	Lavaka	E046° 57' 30.3" S17° 38' 05.3"	653	2.5YR 4/2	14	<5 %	6.5		18
31	Lavaka	E046° 59' 27.6" S17° 41' 50.3"	841						8
32	Grassland	E047° 01' 08.5" S17° 46' 47.5"	1,127			<5 %			2
33	Lavaka	E047° 01' 26.3" S17° 48' 44.8"	1,202			<5 %			9
34	Lavaka	E047° 01' 43.8" S17° 50' 12.5"	1,448			<5 %			10
35	Grassland	E047° 01' 44.4" S17° 50' 11.9"	1,451			<5 %			2

Forest cover distribution in the study sites consists of two types: Forests associated with riparian habitats (Figure 3C, Appendix 2A, D, arrows), and forest fragments associated with lavakas (Figure 3C, arrow heads, Appendix 1B, Appendix 2B).

Grassland, riparian and lavaka habitats (sampled during the dry season) have 85 identifiable species associated with the habitats. Grasslands consistently had an average of 2.94 species (SD = 1.48). Two species of grass, *Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult and *Hyparrhenia rufa* (Nees) Staph are associated with a majority of the sites. Riparian habitats had an average of 10.9 taxa (SD = 5.72), and lavakas averaged 10.38 taxa (SD = 4.31) per location and are not significantly different. The number of taxa associated with riparian and lavaka habitats are significantly higher than the number of taxa in grasslands (Table 1, Figure 4).

TABLE 2. Percentages of water (blue), lavaka / riparian forest (green) and grassland (yellow) of the 93,636 ha at study sites A, B, and C, in Figures 2A.

Habitat	Study Area A	Study Area B	Study Area C
Water	3899 (4.2 %)	119 (0.1 %)	983 (1.1 %)
Lavaka-Riparian Forest	25201 (26.9 %)	24428 (26 %)	44339 (47.4 %)
Grassland	64536 (68.9 %)	69089 (73.8 %)	48314 (51.6 %)

Soil color, moisture content, and pH are all very similar among the three habitats and exhibit no significant differences (Table 1). Soil compaction, however, is severe in the grasslands habitats (averaging a Lang penetrometer reading of 17.9, SD = 1.1), and is significantly lower in the lavakas (two readings that average 14), and riparian habitats (average 9.7, SD = 2.7) (Table 1, Figure 5).

DISCUSSION

Lavaka formation has been attributed to human activity, particularly deforestation, controlled burns and wildfire (Appendix 1A). It has been assumed that the deforestation of the central highlands is a result of a combination of the above factors and poor environmental management. There is no doubt that erosion from the lavakas contribute to the high bed loads observed in the rivers during the wet season. However, only a small percentage of these geomorphic features can unequivocally be linked to human activity. The formation, maintenance, and succession of lavakas may represent a natural geomorphic phenomenon resulting from climatic patterns (strong wet and dry season) (Appendix 1B), edaphic features, ongoing tectonic uplift of the central highlands that maintains a high angle of repose (Table 1), groundwater sapping, and continuous seismic activity (Figure 1) (Wright 1974, de Wit 2003).

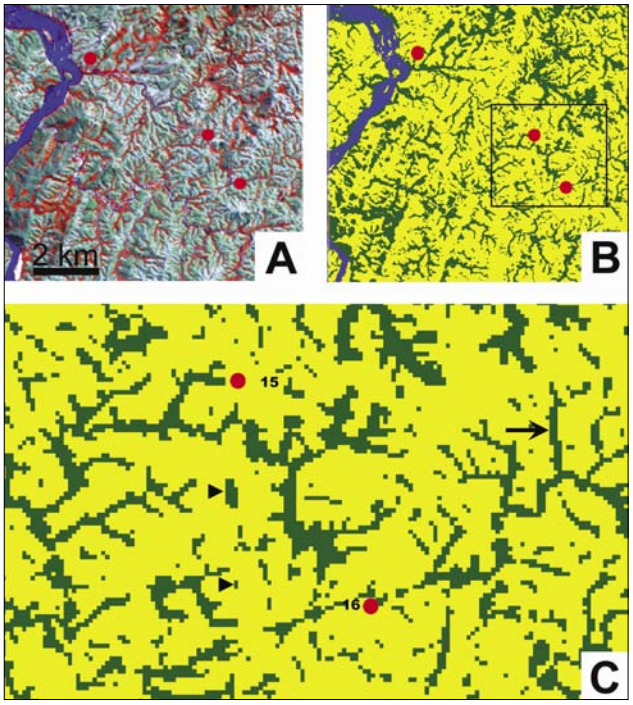


FIGURE 3A. Satellite image of a smaller area of study area A showing the location of some of the sample sites.
FIGURE 3B. Same area as in Figure 3A showing the distribution of grassland, lavaka and riparian forest, and water. The area inside the box is also in Figure 2A area A and Figure 2B.
FIGURE 3C. The area outlined in Figure 3B showing the distribution of grassland (yellow) and, lavaka and riparian forest (green). Note the long linear nature of riparian vegetation (arrow) and the numerous isolated lavaka forests interspersed between the continuous riparian vegetation (arrowheads). The upper left hand corner of the figure has Longitude and Latitude coordinates of E 046° 51′ 46.5″ S 17° 11′ 32.6″.

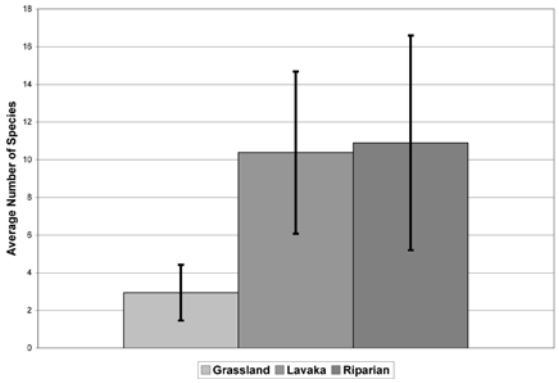


FIGURE 4. Average number of species in each habitat type. The lavaka and riparian habitats have significantly more taxa than the grasslands (the 0.01 confidence interval is indicated by the vertical bars).

The present study attempted to determine recruitment of new erosion features over a 20-25 year-period by comparison of a 1984 Landsat Thematic Mapper satellite data with the 2003 ETM+ data. We found no new recruitment of features in our study area suggesting that all of the current features exceed an age of 20 years. Recent C^{14}-dating of carbon derived from lavakas in other areas of the central highlands indicate an age in the thousands of years for some lavakas, suggesting lavakas may be older than the first human occupation (Cox et al. 2009), and may represent geomorphic features much more persistent than previously suspected (Wright 1974).

Charcoal has been found in lake cores suggesting that wildfire was a disturbance factor prior to human occupation (MacPhee et al. 1985, Burney 1987abc, 1988, 1993). This also suggests that although humans continue to use fire, they may be doing so to manage the habitats of the central highlands by simulating and controlling a disturbance factor that was already in place when humans first arrived in Madagascar (Wright 1974).

The present study indicates that the vegetation associated with riparian habitats and with Type II-IV lavakas (Wells et al. 1991, Wells and Andriamihaja 1993, 1997) comprises 24-45 % of the forest cover on the central highlands (Appendix 1B, Table 2). Often, the initial formation of lavakas and the successional vegetation that they harbor are isolated from the main drainage basin (Figure 3C, Appendix 1C). If lavakas are as long lived

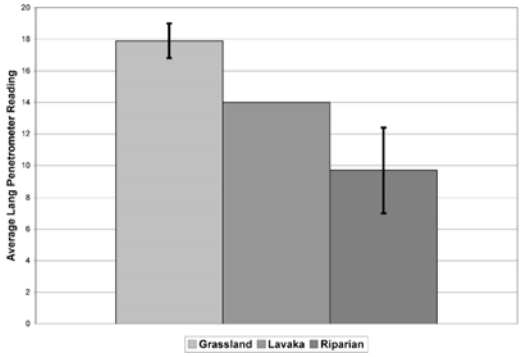


FIGURE 5. The average Lang pentronmeter readings for each habitat type. Grasslands exhibit significantly greater soil compaction than the riparian habitat (the 0.01 confidence interval is indicated by the vertical bars). The average reading for the two lavakas sampled were exactly the same, which is below the grasslands and similar to the riparian habitat; however, there were too few average readings in the lavakas to establish a reliable confidence interval.

as the data suggests, their vegetation may also be genetically isolated from the more continuous riparian forests. Depending on pollination biology of the individual taxa, this may restrict gene flow among the isolated forest populations in the lavakas (e.g., Wright 1974, Shaffer 1981, Pimm et al. 1988, Honnay et al. 1999). Rivers and watersheds as isolating features have been hypothesized as playing an important role in contributing to Madagascar's biodiversity (Martin 1972, Goodman and Ganzhorn 2004, Pastorini et al. 2005, also see Pearson and Raxworthy 2009) and the isolating effects of watersheds that traverse elevational changes may be intensified especially during periods of climatic change (Wilmé et al. 2006).

The association of forests in the central highlands with riparian and lavaka habitats, and the lack of forest cover on adjacent grassland, or the occurrence of successional vegetation associated with grassland suggests that the forest development may be associated with changes in soil moisture availability (Pennington et al. 2000). Soils associated with lavakas, riparian and grassland habitats were tested for moisture content during the dry season. Moisture content was similar in all habitats suggesting that soil moisture may not be a major factor in vegetation patterning (Table 1).

Nutrient availability plays a role in vegetation patterning (Pennington et al. 2000). Lavakas are believed to form by the collapse of the soil surface due to groundwater sapping at the soil-saprolite interface. The ground water sapping appears to be gradual and incremental (Appendix 1B) in lavakas that are isolated from human activity. As ground water sapping continues to efface the nutrient poor soils, the root zone comes into closer and closer proximity to the less nutrient poor saprolite and ground water. Such a process may initiate the development of Type II-IV lavakas that characteristically have well developed vegetation in comparison with the nutrient poor grasslands (Appendix 1B, C).

Another difference between lavaka and riparian habitats and the grasslands is the significant difference in soil compaction (Figure 5). Soil penetrometers mimic plant roots. The higher the penetrometer reading the greater the compaction and greater the difficulty plant roots have penetrating the soil. Grasslands exhibited high readings (average of 17.9), a compaction profile that may limit the ability of a variety of species to establish root growth (Table 1, Figure 5). This reading in an agricultural situation would require deep tillage to promote plant root growth and establishment of the crop plant. Lavaka and riparian habitats have average readings of 14 and 9.7, respectively, readings within a range that permits root establishment (Table 1, Figure 5). Thus, differences in vegetation patterning and diversity may be due to the ability of plants to establish root growth. There is an inverse relationship between species diversity and soil compaction in the three habitats (Figures 4, 5). The mobility of the soils in lavaka and riparian habitats may relieve surficial and subsurface compaction and naturally simulate tilling.

It is interesting that the people of the central highlands often place their tiered and cultivated fields down slope of the drainage incisions of the lavaka (Appendix 1D, arrow). The placement of these agricultural fields may receive the benefit of improved soil moisture due to run off from the lavaka, improved nutrient availability due to the erosion of the exposed saprolite in the lavaka, and the mobility of these soils may relieve soil compaction permitting better root establishment. This practice may slow erosion rates and reduce bed loads. Future investigation will focus on characterizing edaphic differences between the lavaka and riparian, and the grassland habitats.

CONCLUSIONS

There is no doubt that human activity in Madagascar is changing the fauna, flora and the landscape. Lavakas may be natural and long-lived geomorphologic phenomena, and may represent a dynamic and novel habitat. It is important to determine if natural occurring lavakas and those induced by human activity have different developmental processes and what role the various erosion features play in the development of Madagascar's floristic and faunal diversity, and landscape evolution.

ACKNOWLEDGEMENTS

We would like to thank Rónadh Cox for her continuing cooperation and collaboration on the formation of Malagasy lavaka. The NASA Rhode Island Space Grant Consortium provided funding for purchasing the Landsat imageries, and the National Geographic Society for funding the field portion of the study. All of the field work was done as an adjunct under the permits and direction of the Missouri Botanical Garden. I would like to thank all of Missouri's research team in Madagascar that were helpful in facilitating the field research. I thank three anonymous reviewers for their detailed reviews of the manuscript and for providing helpful comments that greatly improved the manuscript.

REFERENCES

Andriamampianina, N. 1985. Les lavaka malgaches : leur dynamique érosive et leur stabilisation. Madagascar Revue de Géographie 46: 69-85.

Bourgeat, F. & Ratsimbazafy, C. 1975. Retouches à la chronologie du Quaternaire continental de Madagascar. Conséquences sur la pédogenèse. Bulletin de la Société Géologique de France 17: 554-561.

Burney, D. 1987a. Pre-settlement vegetation changes at Lake Tritrivakely, Madagascar. Palaeoecology of Africa and Surrounding Islands, 18: 357-381.

Burney, D. 1987b. Late Holocene vegetational change in central Madagascar. Quaternary Research 28: 130-143.

Burney , D. 1987c. Late Quaternary stratigraphic charcoal records from Madagascar. Quaternary Research 28: 274-280.

Burney, D. 1988. Modern pollen spectra from Madagascar. Palaeogeography, Palaeoclimatology, Palaeoecology 66: 63-75.

Burney, D. 1993. Late Holocene environmental changes in arid southwestern Madagascar. Quaternary Research. 40: 98-106.

Cox, R., Rakotondrazafy, A. F. M. and Bakoariniaina, L. N. 2003. Geological controls on development of erosional gullies (lavaka), central Madagascar. Geological Society of America Abstracts 35, 6: 64. (doi:10.1086/598945)

Cox, R., Rakotondrazafy, A. F. M. and Rakotondramazava, H. T. 2004. Geological versus human controls on lavaka formation and extreme erosion in Madagascar. Geological Society of America Abstracts 36, 5: 171.

Cox, R. Bierman, P, Jungers, M. C. and Rakotondrazafy, A. F. M. 2009. Erosion rates and sediment sources in Madagascar inferred from ^{10}Be analysis of lavaka, slope and river sediment. The Journal of Geology, 117: 363-376. (doi:10.1086/598945)

de Wit, M. J. 2003. Madagascar: Heads it's a continent, tails it's an island. Annual Review of Earth and Planetary Sciences 31: 213-248. (doi:10.1146/annurev.earth.31.100901.141337)

Enquêtes Prioritaires auprès des Ménages. 1999. Rapport principal 2000. Antananarivo, Institut National de la Statistique (INSTAT) 191.

Gade, D. W. 1996. Deforestation and its effects in highland Madagascar. Mountain Research and Development, 16, 2: 101-116.

Goodman, S. M. and Ganzhorn, J. U. 2004. Biogeography of lemurs in the humid forests of Madagascar: The role of elevational distribution and rivers. Journal of Biogeography 31, 1: 47-55. (doi:10.1111/j.1365-2699.2004.00953.x)

Helfert, M. R. and Wood, C. A. 1986. Shuttle photos show Madagascar erosion. Geotimes 31: 4-5.

Hoeblich, J. & Hoeblich, J.-M. 1983. L'organisation du relief dans les environs de Tananarive. Madagascar Revue de Géographie 43: 11-39.

Honnay, O., Endels, P., Vereecken, H. and Hermy, M. 1999. The role of patch area and habitat diversity in explaining native plant species richness in disturbed suburban forest patches in northern Belgium. Diversity and Disturbance 5: 129-141.

Hurault, J. 1971. La signification morphologique des lavaka. Revue de Géomorphologie Dynamique 20: 121-128.

Klein, J. 2002. Deforestation in the Madagascar highlands – established 'truth' and scientific uncertainty. GeoJournal 56: 191-199. (doi:10.1023/A:1025187422687)

Kull, C. A. 2000. Deforestation, erosion, and fire: Degradation myths in the environmental history of Madagascar. Environment and History 6, 4: 423-450. (doi:10.3197/096734000129342361)

MacPhee, R. D. E. and Burney, D. A. 1991. Dating of modified femora of extinct dwarf Hippopotamus from southern Madagascar: Implications for constraining colonization and vertebrate extinction events. Journal of Archeological Science 18, 6: 695-706.

MacPhee, R. D. E., Burney, D. A. and Wells, N. A. 1985. Early Holocene chronology and environment of Ampasambazimba, a Malagasy subfossil Lemur site. International Journal of Primatology 6, 5: 463-489. (doi:10.1007/BF02735571)

Martin, R. D. 1972. Adaptive radiation and behavior of the Malagasy lemurs. Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences 264, 862: 295-352.

Pastorini, J., Thalman, U. and Martin, R. D. 2003. A molecular approach to comparative phylogeography of extant Malagasy lemurs. Proceedings of the National Academy of Sciences of the United States of America 100, 10: 5879-5884. (doi:10.1073/pnas.1031673100)

Pennington, R. T., Prado, D. E., and Pendry, C. A. 2000. Neotropical seasonally dry forests and Quaternary vegetation changes. Journal of Biogeography 27, 2: 261-273. (doi:10.1046/j.1365-2699.2000.00397.x)

Pearson, R. G. and Raxworthy, C. J. 2009. The evolution of local endemism in Madagascar: Watershed versus climatic gradient hypothesis evaluated by null biogeographic models. Evolution 63, 4: 959-967. (doi:10.1111/j.1558-5646.2008.00596.x)

Petit, M. & Bourgeat, F. 1966. Étude morphologique du bassin versant de la Tafaina (centre de Madagascar). Comptes Rendus de la Semaine Géologique de Madagascar 1965: 9-12.

Pimm, S. L., Jones, H. L., and Diamond, J. 1988. On the risk of extinction. The American Naturalist 132: 757-785. (doi:10.1086/284889)

Pique, A., Laville, E., Chotin, P., Chorowicz, J., Rakotondraompiana, S. & Thouin, C. 1999. L'extension à Madagascar du Néogène à l'Actuel : arguments structuraux et géophysiques. Journal of African Earth Sciences 28, 4: 975-983.

Raharijaona-Raharison, L. J. & Randrianarison, J. 1999. Facteurs géologiques et climatiques influençant l'érosion en lavaka et ensablement des rizières: le cas du massif d'Ambohitrandriampotsy du sud du Lac Alaotra. In: Actes du 4e colloque international organisé par l'Association pour les Montagnes Africaines (AMA). H . Hurni & J. Ramamonjisoa (eds.), pp 159-172. Association pour les Montagnes Africaines, Antananarivo.

Randrianarijaona, P. 1983. The erosion of Madagascar. Ambio 12, 6: 308-311.

Riquier, J. 1954. Étude sur les "lavaka". Mémoires de l'Institut Scientifique de Madagascar 6: 169-189.

Shaffer, M. L. 1981. Minimum population sizes for species conservation. BioScience 31, 2: 131-134.

Tricart, J. 1953. Érosion naturelle et érosion anthropogène à Madagascar. Revue de Géomorphologie Dynamique 5: 225-230.

United States Agency International Development (USAID), 1998. USAID Congressional Presentation FY 1998. Madagascar.

United States Agency International Development (USAID), 2000, USAID Congressional Presentation FY 2000. Madagascar.

United States Agency International Development (USAID), 2002, USAID Congressional Presentation FY 2002. Madagascar.

Wells, N. A., Andriamihaja, B. and Rakotovololona, H. F. S. 1991. Patterns of development of lavaka, Madagascar's unusual gullies. Earth Surface Processes and Landforms 16, 3: 189-206. (doi:10.1002/esp.3290160302)

Wells, N. A. and Andriamihaja, B. 1993. The initiation and growth of gullies in Madagascar: are humans to blame? Geomorphology 8, 1: 1-46.

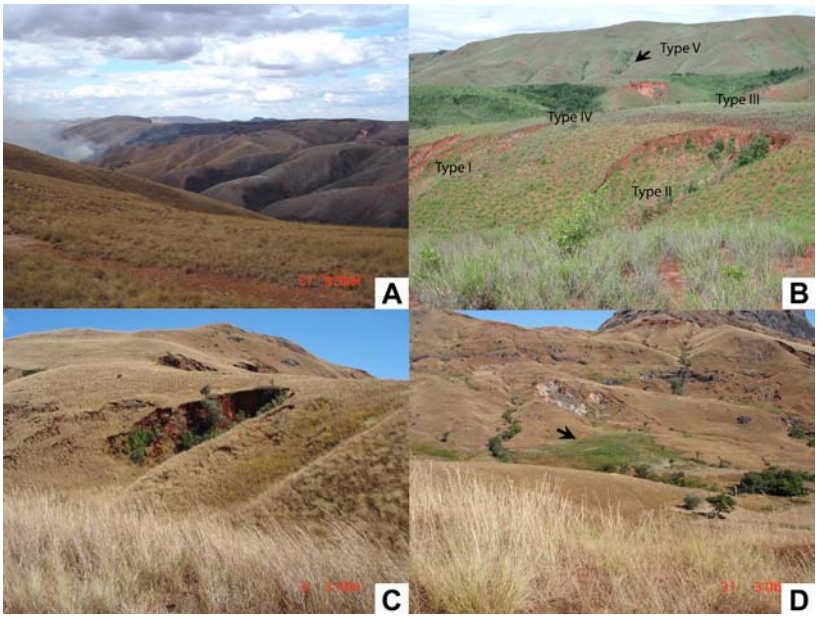
Wells, N. A. and Andriamihaja, B.. 1997. Extreme gully erosion in Madagascar and its natural and anthropogenic causes. In: Natural Change and Human Impact in Madagascar. S. M. Goodman and B. D. Patterson (eds.), pp 44-47. Smithsonian Institution Press, Washington.

Wilmé, L., Goodman, S. M., and Ganzhorn, J. U. 2006. Biogeographic evolution of Madagascar's microendemic biota. Science 312: 1063-1065. (doi:10.1126/science.1122806)

World Bank, USAID, Coopération Suisse, UNESCO, UNDP, and WWF. 1986. Madagascar Environmental Action Plan Vol. 1, Analysis and Advisory Work Report No. E21.

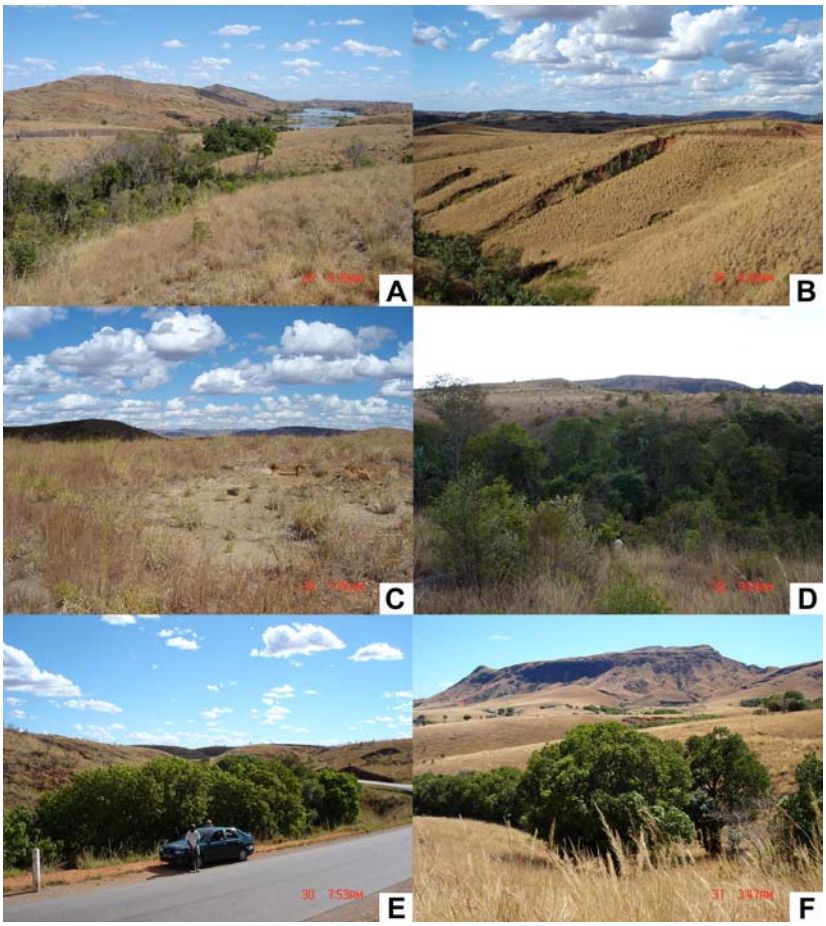
Wright Jr., H. E. 1974. Landscape development, forest fires, and wilderness management. Science 186: 487-495. (doi:10.1126/science.186.4163.487)

APPENDIX



APPENDIX 1.

1A. Example of the widespread use of fire to maintain the grassland; these events may have been a natural feature of Madagascar prior to the arrival of humans. 1B. Lanscape photograph showing the development of Type I-V lavakas. Type I and II lavaka are characterized by the collapse of the soil surface leaving steep amphitheater like walls. Note the well developed vegetation in the Type III and IV lavakas in the background. Farther up slope and further in the background note the Type V lavakas showing the diminishing vegetation and the peneplanation of the steep side walls. 1C. A well developed Type III or IV lavaka showing steep side walls and the well developed vegetation in the lavaka. It is estimated that the development of lavaka may be on the order of thousands of years. 1D. Note the agricultural use of the splay deposit at the mouth of the thalweg (arrow). These agricultural modifications of the drainage egress of the lavaka reduce the erosional rates within the lavaka and have a stabilizing effect.



APPENDIX 2.

2A. Sample site 9 looking north showing riparian vegetation. 2B. Sample site 19 looking north showing a series of well defined lavakas with forest and the linear riparian vegetation on the bottom left. 2C. Sample site 15 looking east showing the grassland vegetation. 2D. Sample site 20 looking west showing the well developed riparian vegetation. 2E. Sample site 16 looking west showing riparian vegetation with *Mangifera indica* Anacardiaceae occupying the riparian zone. 2F. Sample site 28 looking south showing an upslope riparian vegetation dominated by *Mangifera indica*.

Survival and growth of seedlings of 19 native tree and shrub species planted in degraded forest as part of a forest restoration project in Madagascar's highlands

Chris Birkinshaw, Mamisoa Andrianjafy[I] and Jean-Jacques Rasolofonirina[I]

Correspondence:
Chris Birkinshaw
Missouri Botanical Garden, BP 3391, Antananarivo 101
Phone: +261 2022 35344
E-mail: chris.birkinshaw@mobot-mg.org

ABSTRACT

Percentage survival and mean percentage change in height were compared for 19 native tree and shrub species planted at Ankafobe Forest, a degraded fragment of highland forest, at ten months after planting. The species varied considerably in both, survival and growth. Best performers included *Macaranga alnifolia* (Euphorbiaceae), *Harungana madagascariensis* (Clusiaceae), *Filicium decipiens* (Sapindaceae) and *Dodonaea madagascariensis* (Sapindaceae). A comparison of survival between relatively short seedlings compared to relatively tall seedlings revealed no significant difference. This information will be used to increase the efficiency of forest restoration at this site.

RÉSUMÉ

Les projets de restauration forestière avec des espèces autochtones se rencontrent dans plusieurs sites à Madagascar. Cependant, il n'y a pas assez d'échange d'informations entre ces projets. Ces échanges sont pourtant importants car ils peuvent améliorer les méthodologies utilisées. Dans cet article les pourcentages de survie et les pourcentages moyens de croissance ont été comparés pour les 19 espèces d'arbres et d'arbustes autochtones plantées dans la Forêt d'Ankafobe, un bloc de forêt dégradée des hautes terres, à 10 mois après la mise en terre. Les plantules ont été produites localement à partir des graines collectées dans la Forêt d'Ankafobe. Le comportement des espèces varie considérablement en termes de survie et de croissance. Les espèces au meilleur comportement par rapport à ces deux variables comprennent *Macaranga alnifolia*, *Harungana madagascariensis*, *Filicium decipiens* et *Dodonaea madagascariensis.* Un fort taux de mortalité et une croissance lente ont été enregistrés pour *Ixora* sp., *Trema orientalis* et *Elaeocarpus hildebrandtii.* La comparaison de la survie entre les plantules relativement petites et les plantules relativement grandes de toutes les espèces confondues n'a révélé aucune différence significative. Cette information sera utilisée pour améliorer la réussite de la restauration de la forêt dans ce site. Néanmoins, une période de suivi plus long est important, tout comme l'identification des espèces propices à la restauration, c'est-à-dire celles qui peuvent améliorer la qualité du sol, créer de l'ombrage ou attirer les agents disséminateurs de graines.

INTRODUCTION

The historic and on-going loss of Madagascar's forest cover is well known (e.g. Sussman et al. 1994, Steininger and Harper 2003, Consiglio et al. 2006, Harper et al. 2008). It is possible to reduce or even reverse this trend by conserving the remaining native forest and restoring forest in areas where it has been lost. Active restoration of Madagascar's native forest is being practiced with increasing frequency as a means of improving connectivity between forest fragments, increasing the forest area, and increasing the area: perimeter-ratio of forest blocks (pers. obs.). In addition to the large scale and well known restoration projects such as the Ankeniheny-Mantadia-Zahamena Biodiversity Conservation and Restoration Corridor Carbon Project; the Fandriana-Marolambo Forest Landscape Restoration Project, and the restoration associated with QMM's mining activities; many existing protected areas (e.g. Réserve Naturelle Intégrale Betampona, Parc National (PN) Ranomafana, PN Masoala) and proposed protected areas (e.g. Ambalabe, Analalava, Mahabo, Sahamalaza, Tampina and Tampolo, (Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program 2005, Birkinshaw et al. 2009) include more modest restoration or at least reforestation using native species activities around their fringes. The production and plantation of the young plants used by these projects requires significant investment yet there is little exchange of knowledge among the diverse practitioners in different parts of the country that could help improve methodologies employed and their resultant impact (but see Holloway (2000) and Pareliussen et al. (2006)).

Here we report on the comparative survival rate of several native tree and shrub species used in a forest restoration project in Madagascar's highlands. The results are also used to compare the survival of relatively short seedlings compared to relatively tall seedlings for all species combined, to test the importance of seedling size in restoration projects.

KEYWORDS: Humid forest, restoration, seedling survival, seedling growth.
MOTS CLEF : forêt humide, restauration, survie des plantules, croissance des plantules.

[I] Missouri Botanical Garden, BP 3391, Antananarivo 101. Phone: +261 2022 32482.

METHODS

STUDY SITE. This research was conducted in the Ankafobe Forest (E47° 11', S18° 06', elevation 1,475 m), a 33 ha forest fragment, located adjacent to Route Nationale (RN) 4 on the Tampoketsa of Ankazobe, 30 km northwest of Ankazobe, at Point Kilométrique (PK) 132, in Ankazobe Commune (Figure 1). The site is about 12 km west of Réserve Spéciale (RS) Ambohitantely, and can be considered an outlier of this large forest remnant because of its similar flora and proximity (pers. obs.). The Ankafobe Forest consists of fragments of humid evergreen forest (Moat and Smith 2007) located within a number of adjacent valleys. The forest is surrounded by anthropogenic grassland dominated by *Trachypogon spicatus*, *Loudetia simplex* and *Aristida similis* (Poaceae). Within the valleys, the forest is relatively sheltered from the strong winds that blow over the Tampoketsa's grasslands and stoke the wild fires that annually burn large areas within this commune (Ratsirarson and Goodman 2000). The former extent of forest on Madagascar's highlands remains unclear but certainly the remaining fragments were once larger as is testified by the occasional presence of trees surviving some distance from the current forest:grassland boundary. All easily accessible parts of the Ankafobe Forest, amounting to approximately 80 % of its area, were commercially exploited for timber in 2002 and then around 30 % of the remaining forest was burnt in 2003 when grassland fires penetrated the degraded vegetation (pers. obs.).

According to Cornet (1974), the climate at Ankafobe Forest can be classified as sub-humid with mists. Two distinct seasons occur; wet and hot between November and April, and dry and cool between May and October. Mean total average annual precipitation measured at RS Ambohitantely is 1,850 mm, with 85 % falling during the wet season. The highest average monthly temperature (23.7 °C) occurs in November, and the lowest (13.5 °C) in August. Fogs are particularly frequent in the dry and cool season (Ratsirarson and Goodman 2000, Pareliussen et al. 2006). The soil at Ankafobe Forest is an acid red laterite with high clay content (Ratsirarson and Goodman 2000).

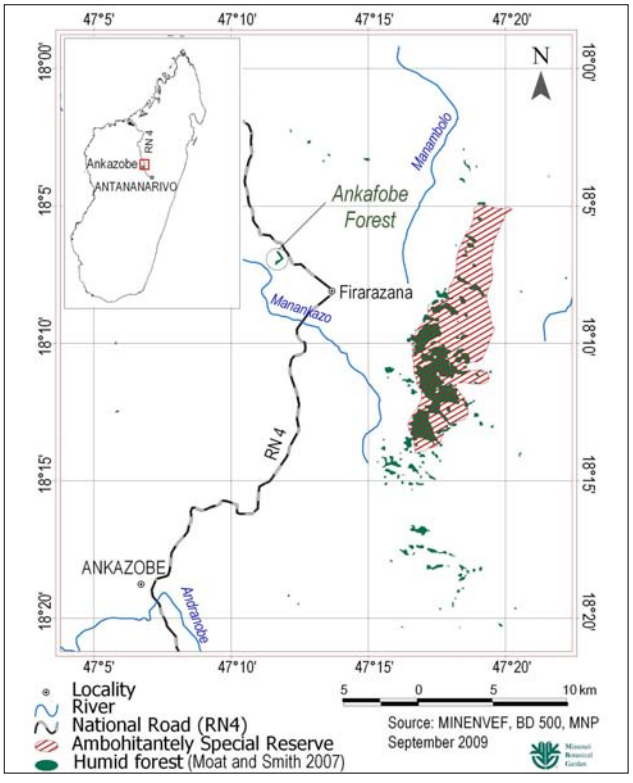


FIGURE 1. Location of study site.

Missouri Botanical Garden, in collaboration with a local, non-governmental association-*Fikambanana Miaro ny Sohisika eto Tampoketsana* (FMST), as well as the *Cantonnement de l'Environnement, des Forêts et du Tourisme* at Ankazobe, and the *École Supérieure des Sciences Agronomiques, Département des Eaux et Forêts, Université d'Antananarivo,* has been implementing since 2004 a program of activities aimed at studying, conserving, and expanding the Ankafobe Forest. This site is important because it contains much of the remaining population of the critically endangered tree *Schizolaena tampoketsana* (Sarcolaenaceae – known locally as *Sohisika*) (Figure 2). We aim to promote the auto-regeneration of the forest at this site by preventing further burning using means of fire breaks and fire patrols. In addition, we are actively attempting to restore parts of the forest that have been burnt and transformed into thicket, shrub-or grassland and therefore have limited potential for auto-regeneration, by planting young plants of native tree and shrub species.

PLANTS USED FOR RESTORATION. In January 2008, a total of 3,500 seedlings from 19 different native species of trees and shrubs were planted (Table 1) in parts of the Ankafobe Forest that had been burnt previously. There was no target list of species and the species used were those for which ripe seed samples could be collected from within the Ankafobe Forest during 2006 and 2007. The species sampled included both heliophiles and sciaphiles. The seedlings had been raised in the Projects' nursery, located at Firarazana (the village closest to Ankafobe Forest (Figure 1)). This outdoor nursery consists of shaded propagation beds constructed of local materials including logs to define the beds and bamboo culms to provide shade. Care was taken to collect ripe seeds. The seeds were cleaned by removing from fruit and washing, checked for obvious signs of predation such as small holes made by insects, and sown immediately into shaded seed beds filled with compost composed of one third well rotted manure, one third river sand and one third dark humus-rich soil collected from the top soil of the forest. When the seedlings had at least one real leaf they were transplanted into polyethylene pots containing compost and grown in shaded nursery beds until two months prior to planting out, when the shade was gradually removed to habituate the plants to full exposure to sunlight. When planted, the seedlings were between 8 to 20 months old, with height ranging from three centimeters to 48 centimeters. Given this very wide range of sizes, it was decided to assess the importance of seedling size on survival (but see Analysis).

PLANTING. The seedlings were planted on the upper slopes of a valley that previously had been forest but now, because of repeated burning over several decades, has been transformed to wooded grassland (as defined by White 1987). This vegetation differs from the surrounding anthropogenic grassland by the presence of occasional trees (remainders from the original forest) and the high abbundance of *Pteridium aquilinum* (Dennstaediaceae) within the herb layer. Planting was conducted early in the wet season because our previous experience has shown that seedling survival is better at this time than during the dry season. Each seedling was planted in a large hole (dimensions: 40 cm x 40 cm x 40 cm) into which

FIGURE 2. Flowering shoot of *Schizolaena tampoketsana* (photo: by kind permission of George E. Schatz).

about half a bucket of well-rotted manure had been mixed with the soil present. Plants were not watered after planting nor were they shaded or weeded because, although probably beneficial, funds were not available for these actions. Four to ten seedlings from each species were selected randomly for monitoring and marked with numbered stakes. The height of each seedling was measured at the time of planting and their survival and height measured again in November 2008, ten months after planting, at the end of the dry season during which period high mortality would be expected.

ANALYSIS. The performance of the various species was compared using the number of plants surviving after ten months, and the mean percentage change in height of living plants. In addition, while the number of seedlings studied for each species was too small to investigate the relationship between seedling height when planted and survival within species, we combined the data for all species to compare survival of relatively short seedlings and relatively tall seedlings. This was done by ranking the individuals of each species according to height when planted, and then grouping the shortest seedlings for each species into one group (mean height = 12.6 cm), and the tallest seedlings for each species into another group (mean height = 19.2 cm). The survivorship of the shortest plants was compared with the tallest plants using a X^2-test (following Campbell 1989).

RESULTS AND DISCUSSION

The percentage survival and mean percentage change in height for the 19 plant species are shown in Table 1. The species varied considerably in both survival and growth. These attributes will be related to both the physiology of the species and its adaptation to the planting environment. A combination of 100% survival and relatively rapid growth was observed for *Macaranga alnifolia*, *Harungana madagascariensis*, *Filicium decipiens* and *Dodonaea madagascariensis*. Low survival and slow growth or size reduction was observed for *Ixora* sp. (Rubiaceae), *Trema orientalis* (Celtidaceae) and *Elaeocarpus hildebrandtii* (Elaeocarpaceae). The poor performance of *Trema orientalis* (only one of four individuals survived and this became shorter because of death of the upper portion of the stem) was unexpected because this species is a succession pioneer that was expected to grow well in degraded habitats. However, Florentine (2008) also found better survival of later successional species than pioneer species in restoration experiments in

TABLE 1. Percentage survival and mean percentage change in height of survivors for 19 native species on Madagascar's highlands, ten months after planting; with comments on each species.

Species	Family	N	% survival	Mean % change in height of survivors	Comments (mainly based on personal observation)
Dodonaea madagascariensis	Sapindaceae	10	100	98	Small shrub, leaves used to feed silkworms. Reported to be an effective colonizer of burnt landscapes (Pareliuseen et al. 2006)
Harungana madagascariensis	Clusiaceae	6	100	96	Small tree, pioneer species, bird-dispersed
Filicium decipiens	Sapindaceae	10	100	75	Medium tree, lemur-dispersed
Macaranga alnifolia	Euphorbiaceae	10	100	56	Shrub or small tree, pioneer species
Dracaena reflexa	Convallariaceae	10	100	43	Shrub, bird-dispersed
Aphloia theiformis	Aphloiaceae	7	100	24	Shrub, bird-dispersed, leaves used to make tisane, pioneer species
Ophiocolea sp.	Bignoniaceae	10	100	16	Shrub or small tree, lemur-dispersed
Tambourissa purpurea	Monimiaceae	10	100	6	Small tree, lemur-dispersed
Uapaca densifolia	Euphorbiaceae	10	90	34	Small tree, lemur-dispersed, frequent species in native forest on the highlands
Schizolaena tampoketsana	Sarcolaenaceae	10	90	29	Medium tree, threatened species
Macphersonia gracilis	Sapindaceae	10	90	25	Small tree, lemur-dispersed
Eugenia sp.	Myrtaceae	10	90	12	Medium tree, lemur- and bird-dispersed
Saldinia sp.	Rubiaceae	10	80	52	Shrub, bird-dispersed
Canarium madagascariense	Burseraceae	10	80	9	Large tree, lemur-dispersed, key stone food species for lemurs
Ravenea madagascariensis	Arecaceae	10	70	37	Medium palm, bird-dispersed
Erythroxylum corymbosum	Erythroxylaceae	10	60	27	Small tree, bird-dispersed
Ixora sp.	Rubiaceae	10	40	2	Shrub, bird-dispersed
Trema orientalis	Celtidaceae	4	25	-68	Shrub or small tree, pioneer species, bird-dispersed
Elaeocarpus hildebrandtii	*Elaeocarpaceae*	7	14	40	Medium tree, lemur-dispersed

Australia. These results can only be considered as preliminary because other studies (e.g. Aronson et al. 2002, Florentine 2008) have shown that in comparisons of species' relative survival and growth, the best performers can change with time. No significant difference (X^2=0.041, df = 1) was found between the survival of the shortest plants compared to the tallest plants for all species combined.

Pareliussen et al. (2006) studied the survival and growth rates of seedlings of five native tree and shrub species planted in grassland at various distances from forest within the RS Ambohitantely. Fifteen months after planting, survival of these species ranged from 40 % to 51 %. The lower survival rate reported in this experiment compared to the current study may be due to its longer experimental period (15 months compared to ten months) and differences in experimental conditions. With respect to the latter, it is notable that Pareliussen et al. (2006) planted their seedlings in grassland whereas in the current study seedlings were planted within wooded grassland at the edge of the former forest where the environment might be expected to be closer to that within the forest. Pareliussen et al. (2006) found best survival close to the forest compared to relatively far from the forest. Pareliussen et al. (2006) also reported significant differences in survival and growth between the five species selected for their study. Two of their five study species (*Dodonaea madagascariensis* and *Filicium decipiens*) were also included in our study, and for these they reported relatively good survival and growth for *D. madagascariensis* but only moderate performance of *F. decipiens*.

CONCLUSION

The native species used in this experiment showed considerable variation in survival and growth rates. The preliminary results suggest that *Macaranga alnifolia*, *Harungana madagascariensis*, *Filicium decipiens* and *Dodonaea madagascariensis* perform well in terms of early survival and growth of seedlings and may be useful species in projects that aim to restore Madagascar highland forest. It is recommended that restoration projects, particularly those of large scale, should conduct trials to investigate survival and growth rates of candidate species rather then blindly investing resources in species that might have poor performance. However, it should also be recognized that survival and growth rates of native tree and shrub species is not the only relevant information for selecting species for restoration projects, and it is likely, that some species considered relatively poor performers on these criteria, may be included in restoration plans because of their importance as restoration facilitators acting, for example, to provide shade, to develop soils, to develop structural complexity or to attract seed dispersers. We found no significant difference in the survival of short versus tall seedlings suggesting that seedlings do not need to occupy tree nurseries for long periods before being planted at a restoration site.

ACKNOWLEDGEMENTS

We would like to thank the *Cantonnement de l'Environnement, des Forêts et du Tourisme* at Ankazobe, for supporting our restoration endeavours at Ankafobe; and the *École Supérieure des Sciences Agronomiques, Département des Eaux et Forêts, Université d'Antananarivo,* for providing us with access to their accommodation and tree nursery at Firarazana. We would also like to thank Dr. James Aronson for commenting on an earlier draft of this manuscript and for his support though the RNC Alliance, as well as three anonymous reviewers, and Christian Camara for translating the abstract into French.

REFERENCES

Aronson, J., Ovalle, C., Avendaño, J., Longeri, L. and Del Pozo, A. 2002. Agroforestry tree selection in Central Chile: Biological nitrogen fixation and early plant growth in six dryland species. Agroforestry Systems 56, 2: 155-166. (doi:10.1023/A:1021345318008)

Birkinshaw, C., Lowry II, P. P., Aronson, J., Lehavana, A., Reza, L., Andrianjafy, M. Rakotoarivony, F. and Rasolofomirino, J-J. 2009. RNC initiatives of the Missouri Botanical Garden. Accessed 30 July 2009 at <http://www.rncalliance.org>.

Campbell, R. C. 1989. Statistics for Biologists. Cambridge University Press, Cambridge.

Consiglio, T., Schatz, G. E., McPherson, G., Lowry II, P. P., Rabenantoandro, J., Rogers, Z. S., Rabevohitra, R. and Rabehevitra, D. 2006. Deforestation and plant diversity of Madagascar's littoral forests. Conservation Biology 20, 6: 1799-1803. (doi:10.1111/j.1523-1739.2006.00562.x)

Cornet, A. 1974. Essai de Cartographie Bioclimatique à Madagascar. Notice Explicative N° 55. ORSTOM, Paris.

Florentine, S. K. 2008. Species persistence and natural recruitment after 14 years in a restoration planting on ex-rainforest land in north-east Queensland. Ecological Management and Restoration 9, 3: 217-224. (doi:10.1111/j.1442-8903.2008.00421.x)

Harper, G. J., Steininger, M. K., Tucker, C. J., Juhn, D. and Hawkins, F. 2008. Fifty years of deforestation and forest fragmentation in Madagascar. Environmental Conservation 34, 4: 325-333. (doi:10.1017/S0376892907004262)

Holloway, L. 2000. Catalysing rainforest restoration in Madagascar. In: Diversity and Endemism in Madagascar. W. R. Lourenço and S. M. Goodman (eds.), pp 115-124. Mémoires de la Société de Biogéographie, Paris.

Moat, J. and Smith, P. 2007. Atlas of the Vegetation of Madagascar. Kew Publishing, Royal Botanic Gardens, Kew.

Ratsirarson, J. & Goodman, S. M. 2000. Généralités sur la forêt d'Ambohitantely. In: Monographie de la Forêt d'Ambohitantely. J. Ratsirarson & S. M. Goodman (eds.), pp 5-9. Recherches pour le Développement. Série Sciences Biologiques. Centre d'Information et de Documentation Scientifique et Technique N. 16, Antananarivo.

Pareliussen, I., Olsson, E. G. A. and Armbruster, W. S. 2006. Factors limiting the survival of native tree seedlings used in conservation efforts at the edges of forest fragments in upland Madagascar. Restoration Ecology 14, 2: 196-203. (doi:10.1111/j.1526-100X.2006.00121.x)

Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program 2005. SANREM CRSP Workshop. Accessed 12 May 2009 <http://www.fishwild.vt.edu/sanrem/sanrem_home.htm>.

Sussman, R., Green, G. M. and Sussman, L. K. 1994. Satellite imagery, human ecology, anthropology, and deforestation in Madagascar. Human Ecology 22, 3: 333-354. (doi:10.1007/BF02168856)

White, F. 1983. The vegetation of Africa, a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa. UNESCO, Natural Resources Research 20:1-356.

REDD comes into fashion in Madagascar

Barry Ferguson

School of International Development,
University of East Anglia
Norwich, Norfolk, NR4 7TJ, U. K.
Phone: +44 (0) 289 181 5566
E-mail: ferguson.barry@gmail.com

ABSTRACT

As the Copenhagen negotiations on the form of post Kyoto mechanisms to tackle climate change approach, firmly on the agenda are proposals to include Reduced Emissions from Deforestation and forest Degradation (REDD). REDD could potentially generate tens of millions of dollars annually for Madagascar, bringing a huge potential to deliver forest conservation and improved livelihoods for the rural Malagasy. Efforts are underway in Madagascar to access REDD finance through a national working group and implementation of five REDD pilot projects. Many areas where the lowering of rates of deforestation is hoped to take place are part of the new generation of protected areas following the 2003 Durban Declaration. These new protected areas are frequently based on federations or grouping of community managed forests, which the literature and experience has shown to be highly problematic and which are rarely fully operational. If REDD is to prove to be an effective conservation tool, as well as an equitable mechanism to promote rural development several issues need to be addressed: More resources allocated to provide direct incentives to communities and to build local management capacity within their forest management associations. More serious efforts are needed to increase forest plantations and to improve management of existing plantations and natural forests, so as to meet the forest product needs of the whole Malagasy population. Basic human rights to have secure tenure of ancestral forest lands, and to derive a decent living from these needs to be recognised and empowered. The risk of 'elite capture' of the revenues generated by REDD should be avoided by the establishment of a transparent and independent scrutiny facility. Finally, it is proposed that improved dialogue between the social critics of conservation in Madagascar and the conservation movement itself should be encouraged.

RÉSUMÉ

Alors que nous entamons les négociations post-Kyoto à Copenhague sur les mécanismes destinés à lutter contre le changement climatique, des propositions portant sur la Réduction des Émissions résultant du Déboisement et de la Dégradation forestière (REDD) sont nettement à l'ordre du jour. En ce qui concerne Madagascar, le programme REDD a la capacité de produire des dizaines de millions de dollars annuellement en permettant la conservation des forêts mais aussi l'amélioration du niveau de vie des populations rurales malgaches. Des efforts sont actuellement consentis à Madagascar pour accéder au financement REDD à travers un groupe de travail national et aussi avec la mise en œuvre de cinq projets pilote. Les endroits dans lesquels un espoir est nourri pour baisser le taux de déboisement sont nombreux et ont tous été inclus dans ce qu'on appelle communément 'les nouvelles aires protégées' conformément à la Déclaration de Durban de 2003. Ces nouvelles aires protégées sont généralement basées sur des regroupements ou fédérations de communautés de base pour la gestion des forêts ; cependant ces groupements ont souvent été reconnues dans les écrits et sur le terrain comme étant pour le moins problématiques et rarement tout à fait opérationnels. Dans ce contexte, REDD pourrait s'avérer être un outil pertinent pour la protection de la nature ainsi qu'un mécanisme équitable pour favoriser le développement rural, sachant cependant que plusieurs aspects devront être appréhendés au préalable. Il s'agira notamment d'allouer davantage de ressources pour attirer effectivement les communautés de base, et simultanément de mettre en place les moyens d'une gestion locale au sein de leurs associations destinées à gérer les ressources forestières. De plus amples efforts devront aussi être consentis pour étendre la superficie des plantations forestières et pour améliorer la gestion des plantations existantes et des forêts naturelles de manière à pouvoir satisfaire la demande en produits sylvicoles de l'ensemble de la population malgache. Parmi les droits fondamentaux, on retrouve le droit d'hériter de la forêt des ancêtres et la possibilité de pouvoir puiser en son sein les ressources vitales pour vivre avec dignité, qui sont des aspects qu'il faudra identifier et respecter. Il existe toujours un risque de discrimination en favorisant une certaine élite avec les revenus produits par REDD, mais ce risque devrait être évité avec la mise en place de contrôles minutieux, transparents et indépendants. Finalement, il est proposé d'ouvrir le dialogue avec les critiques sociaux à Madagascar et d'encourager le mouvement de la protection de la nature proprement dit.

KEYWORDS: REDD, community forest management, human rights, PES, deforestation.
MOTS CLEF : REDD, gestion communautaire des forêts, droits de l'homme, PSE, déforestation.

INTRODUCTION

Madagascar is well known as a global biodiversity conservation priority, and since the early 1990s has often been at the forefront

of innovation in conservation policies in the developing world. Integrated Conservation and Development Projects (ICDPs) (Gezon 1997, Marcus 2001), Community Forest Management (CFM) (Bertrand and Weber 1995, Antona et al. 2004), Ecoregion Based Conservation (Cowles et al. 2001, Fenn 2003) and a new generation of community and co-managed protected areas (Raik 2007, Gardner et al. 2008) are among the initiatives which have been rolled out across Madagascar since the start of the National Environmental Action Plan (NEAP). Among the latest additions to the portfolio of conservation approaches in Madagascar is a system of Payments for Ecosystem Services (PES) designed to reduce the CO_2 emissions produced by deforestation and forest degradation. Known as REDD (Reduced Emissions from Deforestation and forest Degradation), this form of PES is part of global efforts to include forest conservation in the post Kyoto mechanisms for tackling climate change. The basic premise of REDD is that countries which have high rates of deforestation and forest degradation, should be facilitated to access finance from carbon markets and trading schemes, in order to pay for the reductions of the rates of forest clearance and degradation which will result in lower carbon dioxide emissions (Ebeling and Yasué 2008, MEFT 2008, Angelsen 2008, Parker et al. 2009). In order to qualify, projects or national schemes would have to ensure, over periods of 30 years, that changes would not lead to 'leakage' of CO_2 emitting activities outside the defined project/national boundary, that their interventions are leading to 'additional' reductions compared to what would already happen. Furthermore it must be demonstrated that reductions are 'permanent'. The issues of additionality and permanence are assessed partly through the establishment of agreed baseline information on what is happening already and by making projections of what is likely to happen with and without intervention. The actual carbon stocks held in the forests are also monitored to demonstrate the storage and sequestration realised. CO_2 emissions reductions generated by sub-national REDD initiatives can already be traded on the voluntary carbon market after accreditation through voluntary standards (e.g., VCS 2007). The aspiration of many stakeholders at the outset of the COP15 talks in Copenhagen is to have REDD recognised by an international regulatory system which will be the successor to the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC). Such a post Kyoto mechanism will allow the trading of national level CO_2 emission reductions through an internationally regulated market and will allow countries that reduce their emissions to generate revenues as a result. It is unclear if and how the sub-national voluntary agreements which exist already will integrate with such national level processes if REDD is included in the new system. Amid the frenzy and excitement about more funding for forest conservation and the increased opportunities to offset emissions, there are sceptics who do not agree with the basic concept of REDD, and others who highlight the inherent difficulties of such a scheme (for more information on this see Hall 2008, Bullock et al. 2009, Livengood and Dixon 2009, REDD Monitor 2009). Criticisms range from the simple fact that forests are not permanent installations, to the matter that 'leakage' of forest use outside sub-national project and state borders can occur and is difficult to monitor. Such leakage could mean that while particular projects and countries may be successful in reducing emissions, that the shifting of forest uses elsewhere would mean that global CO_2 emissions would not actually be reduced. Also of concern to commentators is the risk of marginalising and impacting negatively of the livelihoods and rights of forest peoples (Rights and Resources Initiative 2008, Colchester 2009, Cotula and Mayers 2009). There are also groups lobbying to ensure that REDD does not allow the conversion of natural forests into plantations to be rewarded, and who wish for biodiversity conservation to be specifically addressed through a more nuanced REDD mechanism, currently being referred to as REDD+ (see Association for Tropical Biology and Conservation 2009, Grainger et al. 2009).

Through both, national and project level REDD processes Madagascar is once again at the forefront of innovation in conservation policies. Since 2008 a national working group (known as the CT-REDD) has been advancing proposals for REDD strategies in Madagascar and five sub-national REDD Pilot projects are now being implemented by international conservation NGOs in partnership with the Malagasy authorities (see Supplementary Material for more detail).

The five REDD Pilot Projects in Madagascar and their implementers:

- Makira – Makira Carbon Company (MCC) and Wildlife Conservation Society (WCS);
- Ankeniheny to Zahamena Forest Corridor (CAZ)– Conservation International;
- Fandriana to Vondrozo Forest Corridor (COFAV)– Conservation International;
- Holistic Forest Conservation Programme (PHCF)– WWF and Good Planet;
- FORECA – GTZ/Inter-cooperation.

Considering the existing rates of deforestation in Madagascar and projections of how much it may be possible to reduce these by, it has been estimated that the potential annual income from a REDD finance mechanism could be worth as much as US $ 72-144 million to Madagascar (Hannah et al. 2008). Through the REDD initiatives underway in Madagascar, specialists are already developing models and methods to deal with the technical issues of measuring and monitoring reductions of deforestation and degradation (Martin et al. 2004a, b, Holmes et al. 2008, Pedroni 2008, Green Synergy 2009, WWF 2009). Three of the five sub-national REDD Pilot Projects (Makira, CAZ and COFAV) are being developed to provide site-based emissions reductions for sale, based on three of the largest new protected areas which have been established in the new Malagasy System of Protected Areas (SAPM). The WCS led Makira project is arguably the most advanced of the three and the Makira Carbon Company was launched in 2008 and is currently finalising accreditation through the Climate, Community and Biodiversity Alliance (CCBA) standards (CCBA 2005, 2008) in order to enter the voluntary carbon market. A fourth REDD Pilot, the Holistic Forest Conservation Programme (PHCF) implemented by WWF and Good Planet combines the development of technical and methodological expertise on deforestation and degradation monitoring with the establishment of over 500,000 hectares of new community managed protected areas as well as extensive habitat restoration. The PHCF is not currently preparing REDD credits for sale, as the WWF Green Carbon Standard, which would facilitate such transactions, is still under development. The fifth REDD Pilot is FORECA, which is implemented by GTZ and Inter-cooperation

and is working in sites across Madagascar to resolve technical issues including the definition of forest, the monitoring of forest change and to deepen the understanding of socio-economic aspects of how the eventual REDD system may function. All five projects are contributing important lessons to the national level process of establishing REDD policies for Madagascar, through their representation on the CT-REDD and through their capacity building components.

CHALLENGES FACING REDD: SOCIAL CONSIDERATIONS

The prospect of accessing tens of millions of dollars annually for forest conservation in Madagascar is an exciting one for the conservation sector on the island, and certainly brings with it great potential to conserve forests and support forest peoples to improve their livelihoods. Many technical challenges such as dealing with additionality, permanence, leakage, monitoring, and forest definition need to be overcome before REDD finance will become a reality for Madagascar. However, this section will leave aside such 'technical issues' and aims to provide some preliminary reflections on the social considerations which will need to be addressed if REDD is to become an equitable and effective conservation and development tool in Madagascar.

There is no shortage of social critiques of the ethics, conception, design and implementation of forest conservation in Madagascar over the period of the NEAP (e.g., Walker 2001, Horning 2004, 2005, 2006, Kaufmann 2006, Pollini 2007, Corson 2008, Harper 2008, Keller 2008, 2009, Muttenzer 2008, Simsik 2008, Sodikoff 2008). While the studies behind these criticisms are often based on particular localities or organisations, they also provide insights relevant across Madagascar's forest conservation policies. Although they may not be specific to REDD, many of the social criticisms of conservation in Madagascar remain largely unresolved and will, unless they are properly dealt with, still act as blockages to achieving the positive outcomes, which it is hoped that REDD will bring. For the purposes of this paper, the following four social challenges are highlighted as being of particular significance for the future success of REDD in Madagascar:

MAKING THE BASIC BUILDING BLOCKS OF CONSERVATION FUNCTION. The Durban Vision of 2003 has led to a massive expansion of terrestrial protected areas across Madagascar. Together the strict protected areas already in existence before 2003 and the new protected areas established since then now cover almost 60% of the remaining forests in Madagascar (see Supplementary Material for details of current forest management regimes). While the older generation of protected areas (National Parks, Special Reserves and Integral Nature Reserves) are typically strict in terms of forbidding most human use, the design of new protected areas is often based on the establishment of community managed forests using the *Gestion Contractualisée des Forêts* (GCF) or *Gestion Locale Sécurisée* (GELOSE) policies, which allow for certain permitted uses. These GCF/GELOSE forests typically have communities living within and close to the forests, and who use them for various aspects of their livelihoods. The literature tells us that of the hundreds of GCF/GELOSE contracts in existence across the island, most are not fully operational because communities and individuals often lack incentives and the capacity to implement the management activities which GCF and GELOSE require them to undertake (Casse 2007, Hockley and Andriamarovololona 2007, Montagne et al. 2007, Raik 2008). These community forestry contracts are the basic management units for many of the areas where deforestation reductions must occur to gain revenue from REDD, but they are currently not working. If REDD is to be successful in Madagascar it is necessary that significantly more resources are allocated to build the capacity of forest managing communities and to provide them with livelihood based incentives to allow them to stop deforestation without experiencing livelihood deterioration.

MEETING THE NEEDS OF MALAGASY FOREST USERS. Most of the people of Madagascar depend on forest products (from plantations and natural forests) for cooking fuel, and many people also depend on forests to provide their construction materials (GISC 2009). People living closest to the forest also depend, to varying degrees, on forest products for food, medicine, livestock fodder and pasture. Also significant are those forest people who currently depend on clearing forest to establish new agricultural land. At present Madagascar's forests are being used faster than they are being replanted, restored and regenerated, leading to an annual rate of deforestation of 0.53% between 2000 and 2005 (MEFT/USAID/CI 2009). In order to meet the needs of a growing population, while aspiring to reduce deforestation and degradation for REDD, a combination of substantial new forest plantations, improved management of existing plantations and the sustainable exploitation and rehabilitation of natural forests will be necessary. In addition, rural farmers who currently depend on *tavy/tetik ala/hatsake* (slash and burn or shifting agriculture) will need to be provided with sustainable livelihood alternatives at a scale substantially greater than that is currently happening. It is recognised that mechanisms to make payments of REDD revenues directly to communities do not currently exist (Nayer 2009) and efforts to provide direct payments for ecosystem services have been directed towards community level projects in health, education and development. While general community development, improved healthcare and education are all very worthy activities in their own right, it has yet to be demonstrated that they are either suitable or adequate as a replacement for household food production based on slash and burn agriculture. It should be a priority in Madagascar to establish new mechanisms to ensure that individuals and households can directly receive revenues generated by REDD in order to compensate them for losses incurred from lowering deforestation and forest degradation.

ENSURING THAT HUMAN RIGHTS TO ANCESTRAL LAND AND LIVELIHOODS ARE RESPECTED AND THAT STAKEHOLDERS UNDERSTAND REDD. It could legitimately be argued that it is a basic human right to be allowed to derive a living from one's own ancestral lands. In Madagascar there is currently a situation where the state rarely recognises either customary forms of tenure over the forest or the associated rights to use the forest for what are perceived locally to be legitimate livelihood purposes. While relative tenure security (SFR) is possible as part of community forestry policies (GOM 1998), it neither recognises individual ownership, nor has it been implemented very often because it is costly and time consuming (Razafindraibe et al. 2007). More recent land tenure reform (GOM 2006) does have the potential to recognise individual customary tenure, but the rapid expansion of protected areas (which disqualifies land from such private tenure recognition) means that most remaining forests are likely to be excluded from such recognition. It is suggested that for REDD to produce an equitable situation to

take account of the human rights of the rural Malagasy, it will be necessary to recognise customary forms of tenure over agricultural and forest lands and to adopt broader consideration of both the concept of 'forest dweller' (World Resources Institute 2009) and that of 'indigenous peoples'. Both, the International Labour Organisation (ILO) Convention 169 (1989) and the 2007 United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) provide a legal basis for these issues to be further explored (Lawlor and Huberman 2009).

AVOIDING EXCESSIVE ELITE CAPTURE. International conservation activities often provide an opportunity for various kinds of 'elites' to gain access to a large share of the resources made available by donors. This dynamic plays out at all scales, from the elites within villages who may dominate forest user groups and capture resources, to government agencies who receive substantial budget support from international donors. It is also significant among international consultants and companies whose expertise is used in project design, management and monitoring, and which is costly. International conservation NGOs also lobby for and receive a great deal of the financial resources available for conservation, in order to maintain the momentum of operations in their organisations (Duffy 2006a, b, Brockington et al. 2008, Corson 2008, Brockington 2009). Once the services and operations of central and regional government agencies, NGOs and consultants have been paid for there are usually very meagre resources remaining for use at the community level. At the international level the carbon-trading sector is also already awash with all manner of entrepreneurs operating on the interface between the private, state and voluntary sectors. With these dynamics in mind, it will be important to ensure that any REDD mechanism in Madagascar can maximise the benefits for local forest users on whose ancestral lands grow the forests which both REDD revenue and local livelihoods will depend upon. It will be essential to have detailed, independent and transparent scrutiny across scales regarding how equitable the distribution of the revenue generated by REDD will be. Of course, consultants, government agencies, NGOs and forest user groups will inevitably all have a role in the future REDD mechanisms, but the local forest users themselves must not be neglected by the conservation movement as they often have been in the past.

CONCLUSION

This paper has strived to provide a very brief overview of the concept of REDD and what is currently underway in this field in Madagascar. It has also identified some of the social challenges which will need to be addressed in order to make REDD equitable for the Malagasy, effective for forest conservation and to result in CO_2 emissions reductions in order to contribute to climate change. Hopefully this will spur more engaged and inclusive discussions in the near future, particularly between social critics of conservation and the conservation movement itself, as this is something which has been somewhat lacking to date (Kaaristo 2008, Ratsimbazafy et al. 2008). Supplementary Material is provided in the form of a report ('REDD in Madagascar: An Overview of Progress') presenting more detailed background information and insights on the issues around REDD in Madagascar.

ACKNOWLEDGEMENTS

I would like to thank the representatives from the conservation organisations in Madagascar who provided information which contributed to this paper: Romuald Vaudry, James MacKinnon, Christian Burren, Richard Lewis, Martin Nicoll, Flavien Rebara, Malika Virah-Sawmy, Bruno Ramamonjisoa, Vololona Rasoarimanana, Monique Andriamananoro, Haniela Randrianjafison, Joana Borges Coutinho and Chris Birkinshaw. Thanks also to Frank Muttenzer, Jacques Pollini, Johannes Ebeling and two anonymous reviewers whose contributions provided corrections, improved my thinking on the subject and enhanced the text considerably. Time spent on the preparation of this paper was partly supported by a NERC/ESRC Doctoral Studentship to the author.

REFERENCES

Angelsen, A. 2008. Moving Ahead With REDD: Issues Options and Implications. Center for International Forestry Research, Bogor, Indonesia.

Antona, M., Biénabe, E. M., Salles, J-M., Péchard, G., Aubert, S. and Ratsimbarison, R. 2004. Rights transfers in Madagascar biodiversity policies: Achievements and significance. Environment and Development Economics 9: 825-847. (doi:10.1017/S1355770X04001640)

Association for Tropical Biology and Conservation and the Society for Tropical Ecology, 2009. The Marburg Declaration, Marburg Germany, 26-29 July 2009. <http://www.atbio.org/> accessed 15 October 2009.

Bertrand, A. and Weber, J. 1995. From State to local Commons in Madagascar: A National policy for Local Management of Renewable resources, Paper presented to the Fifth Common Property Conference 'Reinventing the Commons' 24-28 May, Bodo, Norway. IASCP.

Brockington, D., Duffy, R. and Igoe, J. 2008. Nature Unbound: Conservation, Capitalism and the Future of Protected Areas. Earthscan, London.

Brockington, D. 2009. Celebrity and the Environment: Fame, Wealth and Power in Conservation. Zed Books, London.

Bullock, S., Childs, M. and Picken, T. 2009. A Dangerous Distraction: Why Offsetting is Failing the Climate and People, Friends of the Earth.

Casse, T. 2007. GELOSE – failure or success? Paper presented at the Conference - Society, natural Resources and Development in Madagascar: Recent Contributions by the Research Community, University of East Anglia, Norwich. 20 March 2007.

Climate, Community and Biodiversity Alliance. 2005. Climate, Community and Biodiversity Project Design Standards (First Edition). Washington D. C. Available at <www.climate-standards.org>.

Climate, Community and Biodiversity Alliance, 2008. Climate, Community and Biodiversity Project Design Standards Draft Second Edition Version 1.0. Arlington, Virginia. Available at <www.climate-standards.org>.

Colchester, M. 2009. Safeguarding rights in the FCPF. Presentation by the Forest Peoples Programme and Rights & Resources Initiative at the Chatham House Dialogue on Forests, Governance & Climate Change. Royal Society, London. 8 July 2009.

Corson, C. A. 2008. Mapping the Development Machine: The US Agency for International Development's Biodiversity Conservation Agenda in Madagascar. Unpub. Ph.D. Thesis, University of California, Berkeley.

Cotula, L. and Mayers, J. 2009. Tenure in REDD: Start-point or afterthought? Natural Resource Issues No. 15. International Institute for Environment and Development, London.

Cowles, P. D., Rakotoarisoa, S., Rasolonirinamanana, H. and Rasoarimanana, V. 2001. Facilitation, participation, and learning in an ecoregion-based planning process: The case of AGERAS in Toliara, Madagascar. In: Biological Diversity: Balancing Interests Through Adaptive Collaborative Management. L. E. Buck, C. C. Geisler, J. Schelhas and E. Wollenberg (eds), pp 407-422. CRC Press LLC, Boca Ranton, Florida.

Duffy, R. 2006a. Global environmental governance and the politics of ecotourism in Madagascar. Journal of Ecotourism 5, 1-2: 128-144. (doi:10.1080/14724040608668443)

Duffy, R. 2006b. NGOs and governance states: The impact of transnational environmental management networks in Madagascar. Environmental Politics 15, 5: 731-749. (doi:10.1080/09644010600937173)

Ebeling, J. and Yasué, M. 2008. Generating carbon finance through avoided deforestation and its potential to create climatic, conservation and human development benefits. Philosophical Transactions of the Royal Society B 363,1498:1917-1924. (doi:10.1098/rstb.2007.0029)

Gardner, C. J., Ferguson, B., Rebara, F. and Ratsifandrihamanana, A. N. 2008. Integrating traditional values and management regimes into Madagascar's expanded protected area system: The case of Ankodida. In: Values of Protected Landscapes and Seascapes: Volume 2 Protected Landscapes and Cultural and Spiritual Values. J.-M. Mallarach (ed.), pp 92-103. IUCN World Commission on Protected Areas.

Gezon, L. 1997. Institutional structure and the effectiveness of integrated conservation and development projects: Case study from Madagascar. Human Organization 56, 4: 462-470.

Fenn, M. D. 2003. The spiny forest ecoregion. In: The Natural History of Madagascar. S. M. Goodman, and J. P. Benstead (eds.), pp 1525-1530. The University of Chicago Press.

GISC, 2009. Etude sur la Production et la Consommation en Produits Forestiers Ligneux à Madagascar, Version actualisée 2009, Report to IRG and USAID Madagascar.

GOM, 1998, Décret n° 98 610 sur la sécurisation foncière relative. Government of Madagascar.

GOM 2006 LOI N° 2006-031 DU 24 NOVEMBRE 2006 Fixant le régime juridique de la propriété foncière privée non-titrée. Government of Madagascar

Grainger, A., Boucher, D. H., Frumhoff, P. C., Laurance, W. F., Lovejoy, T., McNeely, J., Niekisch, M., Raven, P., Sodhi, N. S., Venter, O. and Pimm, S. L. 2009. Biodiversity and REDD at Copenhagen, Current Biology 19, 21: R974-976. (doi:10.1016/j.cub.2009.10.001)

Green Synergy. 2009. Réduction des émissions de GES dues au déboisement et à la dégradation des forêts à Madagascar : Etat des lieux et expériences en cours. Unpub. Report to the Madagascar REDD Technical Committee.

Hall, R. 2008. REDD Myths: A critical review of proposed mechanisms to reduce emissions from deforestation and degradation in developing countries, Friends of the Earth International Issue: 114.

Hannah, L., Radhika, D., Lowry II, P. P., Andelman, S., Andrianarisata, M., Andriamaro, L., Cameron, A., Hijmans, R., Kremen, C., MacKinnon, J., Randrianasolo, H. H., Andriambololonera, S., Razafimpahanana, A., Randriamahazo, H., Randrianarisoa, J., Razafinjatovo, P., Raxworthy, C., Schatz, G. E., Tadross, M. and Wilmé, L. 2008. Climate change adaptation for conservation in Madagascar. Biology Letters 4, 5: 590-594. (doi:10.1098/rsbl.2008.0270)

Harper, J. 2008. The environment of environmentalism: Turning the ethnographic lense on a conservation project. In: Greening the Great Red Island: Madagascar in Nature and Culture. J. C. Kaufmann (ed.), pp 241-274. Africa Institute of South Africa.

Hockley, N. J. and Andriamarovololona, M. M. 2007. The economics of community forest management in Madagascar: Is there a free lunch? USAID Antananarivo.

Holmes, C., Ingram, J. C., Meyers, D., Crowley, H. and Victurine, R. 2008. Forest Carbon Financing for Biodiversity Conservation, Climate Change Mitigation and Improved Livelihoods: the Makira Forest Protected Area, Madagascar, Wildlife Conservation Society Report to USAID, August.

Horning, N. R. 2004. The Limits of Rules: When Rules Promote Forest Conservation and When they do not – Insights from Bara Country, Madagascar. Unpub. Ph. D. Thesis, Cornell University.

Horning, N. R. 2005. The cost of ignoring rules: Forest conservation and rural livelihood outcomes in Madagascar. Forests, Trees and Livelihoods 15, 2:149-166.

Horning, N. R. 2006. Strong Support for Weak Performance: State and Donors' Mutual Dependence in Madagascar, Paper Presented at the 11th Biannual meeting of the International Association for the Study of Common Property, Bali, Indonesia 19-23 June 2006.

Kaarista, M. 2008. The reluctant anthropologist: An interview with Maurice Bloch. <www.eurozine.com/articles/2008-02-28-bloch-en.html> accessed 20 November 2009.

Kaufmann, J. C. 2006. The sad opaqueness of the environmental crisis in Madagascar. Conservation and Society 4, 2: 179-193.

Keller, E. 2008. The banana plant and the moon: Conservation and the Malagasy ethos of life in Masoala, Madagascar. American Ethnologist 35, 4: 650-664. (doi:10.1111/j.1548-1425.2008.00103.x)

Keller, E. 2009. Who are "They"? Local understandings of NGO and state power in Masoala, Madagascar, Tsantsa 14: 11-20.

Lawlor, K. and Huberman, D. 2009. Reduced emissions from deforestation and forest degradation (REDD) and human rights, In Rights-based approaches: Exploring issues and opportunities for conservation, J. Campese, T. Sunderland, T. Greiber and G. Oviedo (eds.), pp 269-286. CIFOR and IUCN, Bogor, Indonesia.

Livengood, E. and Dixon, A. 2009. REDD and the effort to limit global warming to 2°C: Implications for Including REDD Credits in the International Carbon Market, Report by KEA3 Limited for Greenpeace International.

Marcus, R. R. 2001. Seeing the forest for the trees: Integrated conservation and development projects and local perceptions of conservation in Madagascar. Human Ecology 29, 4: 381-397. (doi: 10.1023/A:1013189720278)

Martin, N., Shoch, D., Pearson, T., Dushku, A. and Grimland, S. 2004a. Measurement and Monitoring Plan for the Andasibe-Mantadia Corridor Restoration and Conservation Carbon Project Madagascar, Report by Winrock International to Conservation International – Center for Environmental Leadership in Business.

Martin, N., Shoch. D., Pearson, T., Dushku, A. and Brown, S. 2004b. Feasibility Study for Avoided Deforestation Project in the Makira Region of Madagascar, Report by Winrock International to Conservation International – Center for Environmental Leadership in Business.

MEFT, 2008. Climate Change Solutions in Madagascar: The Role of Forests, Repoblikan'I Madigasikara, Ministry of Environment, Forests and Tourism.

MEFT, USAID & CI. 2009. Evolution de la couverture des forêts naturelles à Madagascar 1990-2000-2005.

Montagne, P., Razanamaharo, Z. & Cooke, A. 2007. Tanteza: Le Transfert de Gestion à Madagascar, Dix Ans d'Efforts. CIRAD and RESOLVE Conseil, Madagascar.

Muttenzer, F. 2008. Integrated fortress conservation in the buffer zone of Ankarafantsika National Park: Malagasy narratives of conservation, participation and livelihoods. In: People, Protected Areas and Global Change: Participatory Conservation in Latin America, Africa, Asia and Europe. Perspectives of the Swiss National Centre of Competence in Research (NCCR) North-South, M. Galvin and T. Haller (eds.), pp 253-286. University of Bern, Vol.3. Geographica Bernesia, Bern.

Nayer, A. 2009 Carbon trading: How to save a forest. Nature 462: 26-29.(doi:10.1038/462026a)

Parker, C., Mitchell, A., Trivedi, M. and Mardas N. 2009. The Little REDD+ Book: An Updated Guide to Governmental and Non-Governmental Proposals for Reducing Emissions From Deforestation and Degradation, Global Canopy Programme, Oxford.

Pedroni, L. 2008. Methodology for Estimating Reductions of GHG Emissions from Mosiac deforestation, RED-NM-001 4 July. BioCarbon Fund.

Pollini, J. 2007. Slash and Burn Cultivation and Deforestation in the Malagasy Rain Forests: representations and Realities, Unpub. Ph. D. Thesis, Cornell University.

Raik, D. B. 2007. Forest management in Madagascar: An historical overview. Madagascar Conservation & Development 2: 5-10.

Raik, D. B. 2008. Governance in Community-Based Forest Management: The Case of Madagascar, Unpub. Ph. D. Thesis, Cornell University.

Ratsimbazafy, J, Rakotoniaina, L. J. and Durbin, J. 2008. Cultural anthropologists and conservationists: Can we learn from each other to conserve the diversity of Malagasy species and culture? In: Greening the Great Red Island: Madagascar in Nature and Culture. J. C. Kaufmann (ed.), pp 301-315. Africa Institute of South Africa.

Razafindraibe, R., Andriambolanoro, D. and Rakotondrasata, M., 2007. Foncier et transfert de gestion : la SFR. In Tanteza: Le Transfert de Gestion à Madagascar. Dix Ans d'Efforts. P. Montagne , Z. Razanamaharo & A. Cooke (eds.), pp. 105-110. CIRAD and RESOLVE Conseil, Madagascar.

REDD Monitor, 2009. REDD: An Introduction. <www.redd-monitor.org/redd-an-introduction> accessed 20 November 2009.

Rights and Resources Initiative, 2008. Seeing People Through The Trees: Scaling Up Efforts to Advance Rights and Address Poverty, Conflict and Climate Change. Washington DC: RRI.

Simsik, M. 2008. The Roles of power and conventional wisdom in biodiversity loss on the Malagasy Highlands. In: Greening the Great Red Island: Madagascar in Nature and Culture. J. C. Kaufmann (ed.), pp 137-156. Africa Institute of South Africa.

Sodikoff, G. 2008. Forest conservation and low wage labour. In: Greening the Great Red Island: Madagascar in Nature and Culture. J. C. Kaufmann (ed.), pp 69-89. Africa Institute of South Africa.

VCS, 2007, Voluntary Carbon Standard: Guidance for Agriculture, Forestry and Other Land Use Projects, 19th November.

Walker, W. M. 2001. Defending the Environment, Conserving Social Life : Global Visions and Local Values in Southern Madagascar, PhD Dissertation, John Hopkins University.

World Resources Institute. 2009. Governance Analysis of FCPF R-PIN Documents, Washington DC.

WWF (World Wide Fund for Nature). 2009. Description of the Holistic Forest Conservation Project. <www.panda.org/fr/wwf_action_zones/madagascar_nature/programme_holistique/> accessed 20 November 2009.

SUPPLEMENTARY MATERIAL.

AVAILABLE ONLINE ONLY:

Report titled ‹REDD in Madagascar: An Overview of Progress.› prepared by Barry Ferguson, 5 November 2009, pp 46.

INTERVIEW MADAGASCAR CONSERVATION & DEVELOPMENT

REDD Madagascar

Tiina Vahanen
Jean Roger Rakotoarijaona
François Busson
Christopher Holmes
Hantaniaina Rabesandratana
Rainer Dolch

Correspondence :
Madagascar Wildlife Conservation / Journal MCD
Anthropological Institute and Museum
University of Zurich
Winterthurerstrasse 190, 8057 Zurich, Switzerland
E - mail: info@journalmcd.net

Interview with Tiina Vahanen, senior officer at the UN-REDD Programme. UN-REDD is a collaborative partnership between United Nations Food and Agriculture Organization, UN Development Programme and UN Environment Programme. The Programme supports countries to develop capacity to reduce emissions from deforestation and forest degradation and to implement a future REDD mechanism in a post-2012 climate change regime. Ms. Vahanen, a forester by background who has worked in the UN system for the past nine years, gives MCD's readership a brief introduction to REDD, and tells us about the role of the UN in REDD globally.

Could you briefly describe what REDD is?

REDD is the abbreviation for 'Reducing Emissions from Deforestation and forest Degradation'. Now there also is 'REDD+', which includes a broader scope that includes sustainable forest management, conservation and enhancement of carbon stocks. But what REDD really means is trying to create a value for forests, so that forests are made more valuable standing than cut down. This does not mean to say that all logging is bad; it simply means that deforestation can be addressed if there is a real value for standing forests.

When did the concept of REDD emerge, and why ?

The concept emerged during the negotiations of the UN Framework Convention on Climate Change, initiated by Papua New Guinea and Costa Rica in 2005. Deforestation and forest degradation contribute almost 20% of current greenhouse gas emissions, more than the entire transport sector globally. This initiative was taken to put emphasis on forests and the urgent activities needed to address deforestation and forest degradation, which many economists have said is one of the most cost-effective ways of actually addressing climate change mitigation.

How many REDD pilot projects are there currently around the world?

There are approximately 40 countries participating around the world with the UN-REDD Programme (nine countries) or with the World Bank's Forest Carbon Partnership Facility (FCPF) in the REDD readiness pilot programmes. Madagascar is part of the FCPF.

Can you speak a little bit more about the role of the UN-REDD Programme and what activities are undertaken in an individual country?

The UN sits with the government, experts and stakeholders and together analyze the country's situation to see what their needs are, and from this draw up a plan to get ready for REDD, to make sure that they will have enough institutional and technical capacity to benefit from any REDD mechanism. These programmes are nationally owned and government-led, but there is always an emphasis – and with UN-REDD it is a requirement – on stakeholder engagement before the funds, approximately US $ 4 million per country, are even released to these countries.

The countries' needs vary greatly; some countries put more emphasis on testing benefit-sharing mechanisms, others are interested in improving governance structure or institutional support. But one common thread that every country has requested is a more robust monitoring system – the measurement, reporting and verification systems (MRVs). The latter is crucial, because if you do not have accurate data and good monitoring systems then you cannot expect to benefit financially from any REDD mechanism, because your emissions reductions have to be verifiable. So that is the effort that many countries are undertaking seriously now.

So the idea is to use these pilot projects to see what works and what doesn't work to focus our future efforts on replicating what has worked in these pilot arrangements. Are these pilot projects influencing the decision making process in Copenhagen?

There are so far few concrete examples of on the ground changes, because both the Programme and REDD are very new, but it's an iterative process, collecting lessons learned and sharing them all the time. At the World Forestry Congress (held in Buenos Aires, Argentina, 18-23 October 2009), Tanzania, Vietnam and Panama were sharing what they have done to improve their national coordination of different REDD and forestry initiatives. Coordination has been a difficult problem in many countries; individual donors, NGOs, and the UN all come in with different initiatives and operate separately. But now steps have been taken by a number of countries to coordinate these efforts, and that's a really valuable step. Countries are building up this expertise, as well as experience with technical details, methodologies, challenges with governance and stakeholder participation, etc. They bring their lessons learned to the climate change negotiations, and I believe this influences the decision-making process. Countries find that REDD is a good example where both developing and developed countries seem to have found commonalities and are actually trying to agree on a REDD mechanism text. It's one of the areas in the climate change negotiations that has advanced faster than any other area.

Have there been any challenges so far in making these pilot projects move forward? Are there any pilot projects that so far haven't been very successful?

There are a lot of challenges. It boils down to the very limited capacity in some countries. Simply not having enough people or having recently changed their government, or where there is no political stability. For them it has been more difficult to just get people around the table and start planning and implementing. There are individual uncoordinated efforts by the multilateral system and the individual bilateral programmes, including both government and non-government initiatives. They go to countries and impose their own particular view and approach and the country doesn't have the capacity to say, thank you but we know what we need, and we don't need that kind of approach. There are a number of examples of this.

How many African countries are involved in these pilot projects?

Three are involved in UN-REDD: Zambia, Tanzania and the Democratic Republic of the Congo. FCPF has more African countries, maybe a dozen or so.

Assuming that there will be a REDD mechanism coming out of Copenhagen, what can any one tropical country expect from this mechanism, and what is expected of that country?

It will depend on what the mechanism will look like, and this is why all the developing countries are there at the negotiating table in designing the mechanism. Nobody knows what it will boil down to at the last minute, but basically there will be some sort of funding mechanism. There will be an encouragement for some sort of market mechanism, but some developing countries are requiring the establishment of either a new fund or using existing mechanisms, such as current multilateral programs like the UN-REDD, the FCPF, or the Global Environment Facility. Of course, a lot of bilateral funds also exist, including fairly significant ones from Norway, Australia, the UK, Germany and others. It remains to be seen how far the details of the agreement can be agreed to in Copenhagen. But if there is even a basic agreement that yes, REDD will be a mechanism in the post-2012 agreement, and yes there will be funding for REDD activities through whatever the final mechanism will be, then that already is a significant step forward.

How will countries benefit from this? That depends on how much individual countries are serious about this and how much individual actors are serious in taking real action on reducing emissions and reducing deforestation. There has to be commitment from both sides, both the donor side to agree that there will be adequate and sustainable funding, and at the same time a clear commitment from developing countries that this is serious business and we are ready to take these activities and actions seriously. That's certainly not a simple problem to solve because of the underlying causes of deforestation such as poverty and the need for food for families.

Looking at Copenhagen, what do you think the role of an African country, like Madagascar, will be at the negotiations? What will they be bringing to the table?

What many tropical forested African countries are bringing to the table is the political willingness and political capital to offer their forests for public good to the world for reducing emissions. But what individual countries bring to the table depends on their forest situation and their political situation. For some countries REDD is really the key issue, for others it is not that significant, depending on their deforestation rate, how REDD is part of the overall development agenda, and what significance the forests have within the country.

The following interviews are with five people engaged in different ways with REDD in Madagascar; Jean Roger Rakotoarijaona (ONE), Francois Busson (Green Synergie), Christopher Holmes (WCS), Hantaniaina Rabesandratana (Intercooperation), and Rainer Dolch (Association Mitsinjo).

Please introduce yourself briefly, and how you are involved with REDD in Madagascar :

Je me présente : Jean Roger Rakotoarijaona. Je suis économiste et Directeur des informations environnementales pour l'Office National pour l'Environnement (ONE).

Je ne suis pas impliqué dans des projets de démonstration REDD mais plutôt responsable de la mise en œuvre de REDD au niveau national. Dans ce cadre, je préside le Comité Technique National REDD (CT-REDD). Ce comité a pour mission d'appuyer techniquement le Ministère de l'Environnement et des Forêts dans la préparation, la négociation et la mise en œuvre de REDD à Madagascar. Actuellement, il est en charge de piloter et de superviser la formulation du Readiness Preparation Proposals (R-PP) du REDD de Madagascar. C'est une sorte de feuille de route sur laquelle le pays indique comment il s'y prendra pour se préparer au REDD, c'est-à-dire pour élaborer la stratégie nationale REDD, établir le scénario de référence et mettre en place le système de suivi.

What are the main lessons you learned and where do you see challenges in the implementation of REDD at local / national level in Madagascar ?

REDD est une occasion pour faire face simultanément aux changements climatiques et à la pauvreté rurale, pour appuyer les services environnementaux et conserver la biodiversité.

La nature et les causes de la déforestation font que les activités éligibles dans REDD doivent dépasser les limites du secteur forestier. Dépasser ces limites signifie qu'il faudra sortir du cercle étroit des objectifs de conservation développant et en mettant en œuvre des approches plus structurantes qui traitent du développement et de l'environnement de manière plus intégrée et surtout au niveau national.

Le principal défi à relever consiste à déterminer dans quelle mesure REDD pourrait contribuer au fondement structurel du développement de Madagascar au lieu d'être considéré seulement comme une manne pécuniaire destinée à financer les actions classiques de la conservation. Il s'agit d'identifier les conditions pour que REDD s'accorde avec les problèmes de fonds de la politique environnementale et donc du développement du pays.

What are your expectations / hopes of the COP15 for Madagascar?

Les pays développés et les pays émergents doivent prendre leur responsabilité et la COP15 doit accoucher d'un accord juridiquement contraignant signé par toutes les Parties à la Convention. Des systèmes incitatifs appropriés doivent être mis en place pour faire participer les autres pays. Cet accord comprendra des objectifs ambitieux de réduction des émissions de gaz à effet de serre ainsi que des engagements clairs en termes de financement, de renforcement de capacités et de transfert de

technologie de la part des pays responsables des changements climatiques pour aider les pays en développement à s'adapter.

Les dossiers pour lesquels les négociations sont relativement avancées doivent être bouclés, c'est le cas de REDD. Il n'est plus question d'apporter des complications supplémentaires, il s'agit de régler certains détails et de faciliter les conditions de mise en œuvre plutôt que de revenir en arrière sur les questions du «scope». REDD+ me paraît être l'option la plus satisfaisante.

Les négociateurs malgaches doivent encourager la finalisation de ces dossiers avancés sans pour autant perdre de vue les discussions de l'accord sur le plan global car Madagascar est avant tout un pays victime qui aura à supporter des coûts importants des conséquences des changements climatiques.

Please introduce yourself briefly, and how you are involved with REDD in Madagascar :

My name is François Busson, and after an academic training as agronomist and forester, I have been working in the field of natural resources management and rural development for some fifteen years. More specifically, I worked as technical advisor of different projects related to protected areas management. As such, I have been working for five years on the 'Tsingy de Bemaraha' project, in Madagascar, during the 1990ies. More recently, I have been the technical advisor of the Guinean Ministry of Environment, and that's when I started getting involved in the implementation of international agreements on environment, and in climate change topics.

In Madagascar, I haven't been engaged in a REDD project as such, but since December 2008, I had the opportunity to be working on the REDD approach at the national level, first by supporting the national technical committee (CT-REDD) within a team of the Green Synergie NGO, and today with a team of the ONF International, as contractor for preparing the methodological components of the national REDD approach, through the RPP (Readiness Preparation Proposal) framework.

So I have rather a general view of the different REDD projects in Madagascar, and my role has been mainly connecting people, and help to integrating the international framework into the national approach.

What are the main lessons you learned and where do you see challenges in the implementation of REDD at local / national level in Madagascar ?

Madagascar has this chance to host already five REDD projects. Three of them (managed by CI and WCS) are located in the eastern part of Madagascar, in the rain forest, and aim at producing carbon credits. They are now finalizing their PDDs. The two others (managed by GTZ / Intercoopération, and WWF / Good Planet) have several different sites, and are more focused on methodology. They mainly try to produce specific approaches and tools (e.g., reference scenario, allometric equations) adapted to the Malagasy context.

It must be underlined that the group of technicians involved in these projects, as well as national administration and technical bodies (as the ONE, Office National de l'Environnement) have been willing to work together and created the CT-REDD (national technical committee for REDD), and helped producing the 'R-PIN' (Readiness Project Idea Note) to allow Madagascar to benefit from World Bank funds to work on a national approach for REDD. Thanks to this joint effort, Madagascar is now preparing its RPP (Readiness Preparation Proposal), the pathway to build a national strategy for REDD, prepare a national reference scenario, and set up appropriate tools for monitoring and verification.

All that sounds very positive and promising, but things are not that easy; REDD is a kind of tricky thing because at the same time it's a very new approach, and it's potentially a valuable source of income. So, on one hand, it is very important that information and lessons learned could be widely spread, but on the other hand there is some competition amongst operators, and the researchers involved in methodological aspects, e.g., they are not keen to disclose their work before it has been published. The result is that the collaborative approach has its limits, and that some results and data gathered at the projects level are not available to help building the national approach.

Another thing has to be clearly understood: That there is a big difference of targets and means between a project approach, aiming at producing carbon credits for the voluntary market, and a national approach linked to international negotiations of the 'post Kyoto' framework. To be clear, the REDD 'pilot projects' in Madagascar have been implemented more as complementary activities, potentially a new source of income for activities of forest protection and management, on sites where the different operators were already working. In this light, it is then less surprising that no REDD pilot project is today addressing the deforestation in the southwest part of Madagascar, where the highest rate of deforestation has been recorded between 1990 and 2005.

Of course, the REDD approach is very complicated, and it is easier, and probably wiser, to start working on it in a place where you already have a good environmental and social knowledge. But this kind of strategy won't always address the key zones of deforestation at the national level. That's why national approach and strategy are strongly necessary. The challenge is to find new ways and means for fighting deforestation, especially in the most threatened zones.

Consistent monitoring and verification tools at the national level are also essentials, and projects should pay more attention in contributing to them in a coherent way because, when the time of selling carbon credits comes, the credibility (and the price...) of these carbon credits will depend on the robustness of these tools.

But it also must be acknowledged that the national approach is hampered by the situation of the national administration. Civil servants of the forest and environment departments seldom have an in depth knowledge of REDD issues, and better capacity building is required. Even more worrying is the political situation with an unstable government, and great difficulties to make strong and clear decisions.

What is your opinion on the potential role of carbon finance in terms of the overall funding needs for conservation in Madagascar?

The potential role is great, but the question is whether it will remain a potential or become reality. We are speaking of a market mechanism, and the very challenge for Madagascar is to be a credible country for such an approach, with transparent mechanisms, clear control on the 'permanence of forests', and comparative benefits with other countries. Otherwise, there won't be any carbon credit issued for REDD in Madagascar...or no one to buy them...

There is a tendency among some of the stakeholders to consider REDD as the new 'gold mine', and they think that dollars will

flow just because there are some forests in Madagascar. But they should understand that this mechanism is linked to a result, and has to be assessed by an international validation process. Key issues like benefit sharing amongst the different stakeholders have to be stated in a clear and transparent way in order to be most efficient to halt deforestation.

What are your expectations / hopes of the COP15 for Madagascar?

Even before Madagascar, my hopes are for the planet. Copenhagen won't be a real breakthrough if the two major players, namely the United States and China don't accept major efforts in reducing their GhG production. If they do, we can hope a real 'chain reaction' of commitments of different countries, and the 'post Kyoto' agreement will be more efficient in struggling against climate change. Within such an agreement, strengthening the importance of forest conservation will obviously benefit to Madagascar. I also hope that this conference will have an important impact in Madagascar, and that national politicians will be more committed in forest protection and sustainable management.

Please introduce yourself briefly, and how you are involved with REDD in Madagascar :

My name is Dr. Christopher Holmes. I am the technical director as well as deputy country program director for the Wildlife Conservation Society Madagascar Program. I have been working with the WCS in Madagascar since 2004. I began my work with WCS Madagascar as the technical director for the Makira Forest Protected Area project, located in the northeast of Madagascar. The Makira project was initiated in 2001. In 2004 a forest carbon feasibility study was carried out to estimate the quantity of carbon emissions avoidance that could be attributed to avoided deforestation through the establishment of the Makira Forest Project and protected area. The initial estimate from this feasibility study indicate that 2.5 million tons of carbon equaling 9.5 million tons of CO_2 equivalent in emissions avoidance are attributable to the Makira Forest Project over a 30-year period. In 2005 Makira was granted temporary status as a protected area. Currently WCS is in the process of developing Makira's Project Design Document (PDD) for Voluntary Carbon Standard (VCS) and Climate, Community and Biodiversity (CCB) certification. Makira is an Avoided Deforestation REDD project.

What are the main lessons you learned and where do you see challenges in the implementation of REDD at local/national level in Madagascar ?

As mentioned, the Makira Forest Project was piloted in 2001: This was well before the development of REDD and the standards to which REDD projects are to be held. The lessons learned for the establishment of Makira as a REDD project are similarly related to those learned from establishing a protected area: It is critically important to engage at the local level and have buy in from the communities bordering the protected area in order to ensure success. Because the success of Makira, as a REDD project, will be measured based on ability to reduce deforestation that is driven by subsistence-based land use practices progress will only come through direct intervention with local communities. Local communities have to have the willingness as well as capacity and opportunity to shift land use practices to those that are sustainable and reduce impact on forests. It is a significant challenge, and one that requires long-term investment and presence, for WCS to engage with the local communities to the degree needed to ensure this shift in resource stewardship.

Challenges related to scaling from a local to national level relate to baseline scenario assessment, monitoring and verification, and carbon revenue management. The idea / appropriateness of such a 'nested' approach to REDD is still debated internationally. In many ways Madagascar is rather advanced: The 15-year evaluation of forest cover and forest loss is an important step toward developing a national baseline, however the modalities of monitoring and particularly mechanisms of revenue management are still in development.

What is your opinion on the potential role of carbon finance in terms of the overall funding needs for conservation in Madagascar ?

I think it is very important not to portray carbon finance as the 'golden egg' in terms of conservation funding in Madagascar. There are numerous issues including additionality, permanence and leakage that need to be well addressed in order to justify forest carbon as a finance mechanism: Forest carbon cannot be applied across the board as a viable solution for conservation financing in Madagascar. That said, carbon finance can contribute to the overall funding needs of conservation in Madagascar, perhaps most appropriately at the site level. Again, the modalities of a national REDD strategy are still being developed.

What are your expectations / hopes of the COP15 for Madagascar ?

In fact, any hopes or aspirations of the COP15 are significant beyond Madagascar. The REDD debate is extremely complex with countries jockeying to have their national interests met: Should there be a consideration of degradation – the second 'D' in REDD; should there be consideration of forest conservation efforts REDD+ – this related to those countries that have historically low deforestation rates such as in many central African countries; should there be consideration for sustainable forest management REDD++ – this relates to reduced impact logging; should there be consideration for enhancing forest carbon stocks REDD+++ – this relates to reforestation efforts. The debate of these issues by governments is driven by where the country sits on the scale of forest cover relative to past and predicted future deforestation rates. Madagascar sits in the low forest cover / high deforestation area of consideration, however, any consensus on REDD will have to take into consideration the interest of those countries that have historically low deforestation rates (e.g., Congo Basin) as well as those that are beginning to reforest (e.g., India and China). Despite the fact that COP15 is just around the corner there is little clarity on these issues.

Please introduce yourself briefly, and how are you involved with REDD in Madagascar?

Je me présente, Hantaniaina Rabesandratana. Je suis la chargée de programme junior en changements climatiques pour Intercooperation depuis 2008. Je suis parmi les personnes en charge d'un projet de recherche-action sur la REDD à Madagascar, appelé REDD Foreca. C'est un projet qui vise à appuyer le Gouvernement de Madagascar dans l'établissement du mécanisme REDD. Pour cela :

- Il lui fournit les éléments nécessaires pour qu'il puisse identifier les forêts à engager pour la REDD à Mada-

gascar à partir d'expériences locales et en considérant les exigences et décisions internationales.
- Il élabore un ensemble d'outils méthodologiques applicables dans les pays en développement permettant de faire une estimation quantitative du carbone forestier, de faire le suivi, de rapporter et de vérifier ce carbone, d'analyser les facteurs et les agents de la déforestation et de la dégradation (DD), d'établir les incitations positives contre la DD et de ressortir le cadre de gouvernance dans lequel s'inscrira le projet REDD FORECA en termes de gouvernance des ressources forestières et gouvernance des incitations.
- Étant membre du comité technique national REDD il nourrit les réflexions nationales pour le développement de la stratégie REDD à Madagascar.

En tant que chargée de programme junior en changement climatique, je participe au projet REDD FORECA en tant que personne ressource locale d'INTERCOOPERATION dans le développement de l'outil incitation et appuie à la coordination du projet en général.

What are the main lessons you learned and where do you see challenges in the implementation of REDD at local / national level in Madagascar?

Cette première année d'expérience au sein du projet m'a permis d'apprendre que dans un mécanisme comme la REDD, où les incertitudes dominent les acquis, il est nécessaire de suivre de près l'évolution des résultats des négociations internationales avant de pouvoir communiquer avec les communautés locales même si l'approche participative est recommandée dans la mise en œuvre des activités.

Les discussions avec des acteurs à tous les niveaux , depuis le niveau local (Communautés), régional (Services déconcentrées et collectivités décentralisées) et national (membres du comité technique national REDD) montrent que des défis sont à relever à tous ces niveaux par rapport aux exigences internationales sur la mise en œuvre de REDD ; il s'agit des besoins en renforcement de capacité (identification des cibles et des besoins pour que l'activité soit efficiente), de l'appui à la réalisation des objectifs des politiques et stratégies sectorielles qui garantissent la meilleure condition de mise en œuvre de la REDD (foncier, anti-corruption, gouvernance, démographie) et la mise en place d'un système de suivi. Plus particulièrement, dans la définition du système d'incitation où les Communautés riveraines des forêts sont les plus impliquées, un des défis à relever est de faire en sorte que la rationalité de ces types d'acteurs soit comprise et tenue en compte par les décideurs nationaux et surtout internationaux (par exemple, la préférence pour le court terme, l'importance de la dimension sociale plus qu'économique).

What is your opinion on the potential role of carbon finance in terms of the overall funding needs for conservation in Madagascar?

Madagascar est parmi les pays qui se sont engagés depuis longtemps dans la conservation de la biodiversité et dans la lutte contre la déforestation et la dégradation des forêts, bien avant REDD ; enrayer la dégradation des forêts constitue même une orientation de la politique forestière qui remonte déjà à 22 ans. À ma connaissance, le taux de déforestation persiste encore même si certains chiffres montrent une tendance à la baisse, plusieurs espèces de faune et de flore ainsi que des habitats sont encore qualifiés de menacées. À mon avis, le mécanisme REDD va renforcer cet engagement du pays dans la conservation et apporte en même temps un financement en plus. Je considère que le rôle innovant et additionnel de ce financement carbone dans la conservation est de contribuer à trouver la solution à deux obstacles au moins auxquels la conservation ne peut apporter que peu de contribution : (i) la faiblesse de l'État surtout en matière de contrôle et de suivi et (ii) le manque de retombées des actions sur les Communautés. Pour moi, ces deux solutions sont transversales à la mise en œuvre ou à l'application des conventions internationales relatives à l'environnement et aux ressources naturelles ; le financement pour les activités propres à la conservation devrait faire l'objet de financement découlant surtout de la Convention sur la Diversité Biologique. Néanmoins, le financement carbone est une opportunité qui se présente pour la conservation car il permettra de conserver l'habitat de la plus grande diversité biologique qu'est la forêt tropicale. Je reste convaincue que si on veut mieux conserver, il faut mieux développer ; et ce financement pour le développement conduisant implicitement à la conservation est le rôle potentiel du financement carbone.

What are your expectations / hopes of the COP15 for Madagascar?

Je pense que ce qui est important pour Madagascar pour avoir une chance de pouvoir mettre en œuvre ce mécanisme REDD est que les négociations internationales conduisent à la reconnaissance de l'approche subnationale pour conduire le projet REDD. Les discussions devraient aussi porter sur les incitations qui doivent être assez conséquentes pour garantir les réductions réelles.

En effet, pour les pays comme Madagascar, où les Communautés sont fortement dépendantes des terres et des ressources forestières et où la capacité pour une bonne gestion de ces ressources n'est pas disponible, les stratégies locales deviennent aussi importantes que la stratégie nationale pour la lutte contre la déforestation. Une décision sur l'allocation de fonds pour la mise en œuvre et le suivi d'un système d'incitation pendant une période « test » suivant une approche subnationale est mon souhait par rapport à cette COP 15.

Please introduce yourself briefly, and how you are involved with REDD in Madagascar :

My name is Rainer Dolch. I am a German expatriate having been living and working in Madagascar for over 15 years. I am coordinator of the Association Mitsinjo, a Malagasy environmental NGO that evolved out of a community project. Mitsinjo manages more than 10,000 ha of rainforest habitat in the Andasibe region, including the SF Analamazaotra and the Torotorofotsy Ramsar site.

Our organization is one of the driving forces in implementing one of the most ambitious projects in Madagascar that links the reduction of carbon emissions with biodiversity conservation and sustainable livelihoods. It is located in the new protected area of Ankeniheny-Zahamena. The project has two components, including a REDD component of 425,000 ha and a reforestation component of 3,020 ha. The latter is usually referred to as TAMS (*Tetik'asa Mampody Savoka*), meaning 'the project to bring back the forest'. The names of the overall project almost change at a faster rate than our planet's climate, and I apologize if I have lost track. If the World Bank is to be believed, it is now called the "Ankeniheny-Zahamena-Mantadia Biodiversity Conservation Corridor and Restoration Project" and the extent

of the name definitely reflects the degree of difficulty to implement the project, which is mainly due to its complexity and number of stakeholders involved.

What are the main lessons you learned and where do you see challenges in the implementation of REDD at local / national level in Madagascar?

Forests do not become automatically protected just because they are subjected to REDD. Even in already 'protected' areas such as Ankeniheny-Zahamena, forest destruction continues. Owing to the political crisis, pillaging of protected areas has now even increased, as we all know, not only in terms of illegal logging. The debate about the rosewood mafia certainly draws a lot more public attention than other issues, but we have to state that slash-and-burn, artisan mining and bushmeat hunting all dramatically increased within protected areas after the regime change. The classic protected areas' issues therefore have to be addressed first: Is protected area status only written on paper? Who is properly surveying protected areas? Why are infractions not prosecuted? How can it be that there are people that do not even know that they are living in a new protected area? What structural measures does the Government take to fight rural poverty? How do we ensure proper community benefits and involvement in the management of natural resources?

Community benefits were obviously not the most imminent concern of the Government in the wake of the political crisis. Difficulties of funding this year's project phase caused a discontinuity of our activities and therefore some grievous setbacks. As a result, project participants were deprived of their benefits and subsequently had to return to engage in environmentally destructive activities to earn their living. If politicians finally agreed upon what is needed for the development and progress of this country, we would certainly see equal development and progress in innovative projects linking climate and biodiversity issues.

When it comes to carbon sequestration projects, REDD or other, there are other challenges as well. The more complex such a project gets, the more difficult it becomes to properly coordinate logistics and administration amongst multiple stakeholders. Projects with a high degree of complexity also often tend to be very hierarchical and top-down rather than bottom-up. Therefore, I see a high risk of neglecting the needs of local communities and community based initiatives that are vital for project success.

So, how do we make sure that REDD benefits local communities? REDD must be a strong incentive for farmers to indeed protect the forest. If they see no direct benefit, the forest will be converted to farmland. We also need money for building capacities and monitoring activities that are needed for adequate management. There is of course the idea of creating a Trust Fund with REDD money that should assure the financing of it all. How can we guarantee that this money is properly managed? So far, however, the development of a national strategy for REDD in Madagascar is only in its beginnings.

It has to be clear that REDD is not just about carbon. It is about biodiversity conservation and improvement of rural livelihoods. From my experience, project managers tend to view REDD rather one-dimensionally, although a variety of aspects have to be taken into account. In my opinion, the strongest incentives for the local population to participate in REDD activities are direct payments and security of land tenure. Project managers would be well advised to address these issues first.

Finally, ecosystem services, carbon sequestration, and REDD have to have larger publicity. In order to get this topic into the mainstream, I would appreciate seeing more knowledgeable journalists reporting about these issues and relevant projects in Madagascar.

What is your opinion on the potential role of carbon finance in terms of the overall funding needs for conservation in Madagascar ?

Carbon finance, as one sub-aspect of payments for ecosystem services, certainly could contribute a lot to overall funding needs for conservation in Madagascar. It all depends on how well or not these funds are managed and to what extent they really benefit local communities. In that sense, we must not forget that REDD is vulnerable to abuse, especially in countries that are not on top of Transparency International's anti-corruption list.

I would definitely appreciate to have at least part of that money as direct payments for local people who assure that these ecosystems and their services are indeed protected. Payments for REDD still raise basic questions as 'who owns the forest?' I am afraid that these have not been adequately addressed yet.

What are your expectations / hopes of the COP15 for Madagascar?

At COP14 in Poznan, Madagascar was already identified as one of the key areas for 'combined climate and wildlife protection'. It is therefore disappointing that Madagascar is not among the recently named tropical countries to directly benefit from UN-financed REDD projects.

I would like to see this change and hope that an agreement on a comprehensive plan for the conservation of the planet's tropical forests will be reached at COP15 in Copenhagen. This would mean that the international community increases their assistance to these countries. In turn, the countries where tropical forests occur should be fully conscious of their special responsibility of preserving these forests. Carbon emissions from deforestation should be taken into account in the future. REDD should be integrated into a post-Kyoto agreement.

It also appears rather odd to me, when companies abroad pay for REDD projects in Madagascar, whereas companies that produce immense carbon dioxide emissions within the country do have no obligations to reduce their emissions whatsoever. This is current practice in mining projects that are responsible for both large deforestation and usage of enormous quantities of fossil fuels in Madagascar. They should be held accountable for their emissions, irrespective of the country in which they occur.

VOICING OVER PICTURES – *PAROLES D'IMAGES*

MALAGASY PEOPLE TALK ABOUT THE COVER PICTURE

DES JEUNES ET DES MOINS JEUNES DE MADAGASCAR NOUS PARLENT DE LA PHOTO DE COUVERTURE

RAHA MBOLA METY AHITAN-DOZA MIANTRA AMIN'NY AIN'NY TSIRAIRAY NY FANEHOAN-KEVITRA AM-PAHIBEMASO MIKASIKA NY ZAVA-MITRANGA SASANTSASANY ETO MADAGASIKARA DIA MANIRY NY HIHODIVITRA NY OLANA TOA IZANY NY GAZETY MADAGASCAR CONSERVATION & DEVELOPMENT. MANANTENA FA MBOLA HO HENO ANY AORIANA ANY IREO FEO NAMPANGININA AMIN'IZAO FOTOANA IZAO.

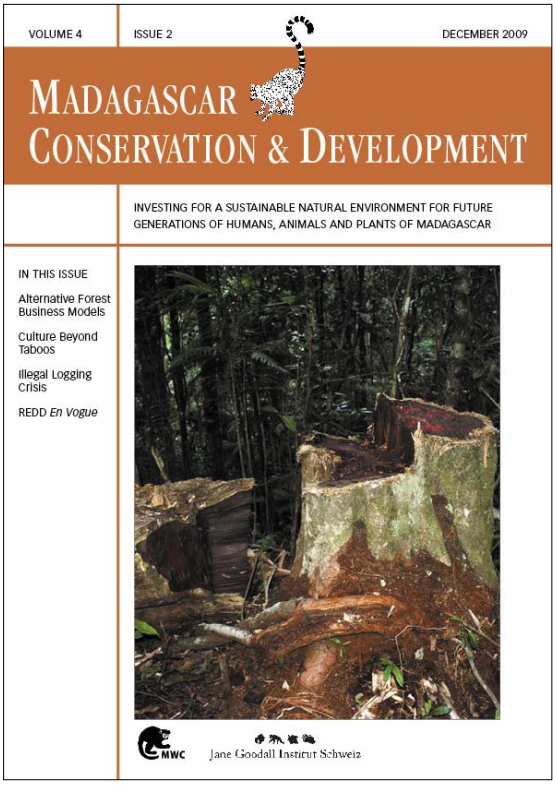
Aussi longtemps qu'il est dangereux de s'exprimer sur certaines questions à Madagascar, le journal Madagascar Conservation & Development se refuse de faire courir des risques à ceux qui voudraient donner leur avis. Le journal souhaite sincèrement que les voix, muettes pour le moment, se feront de nouveau entendre dans un proche avenir.

As long as voicing opinions on certain subjects in Madagascar places the lives of any individuals expressing their viewpoints at risk, the journal Madagascar Conservation & Development wishes to avoid creating any such problems. The journal sincerely hopes that the voices, muted for now, will be heard again in the near future.

IMPRESSUM

Madagascar Conservation and Development is the journal of Madagascar Wildlife Conservation (MWC) and the Jane Goodall Institute (JGI Switzerland). It is owned by these two institutions and is produced in these institutions own responsibility.

ISSN 1662-2510
Madag. conserv. dev.



Madagascar Conservation & Development is the journal of Madagascar Wildlife Conservation (MWC) and the Jane Goodall Institute (JGI Switzerland). It is produced in these institutions' own responsibility.

All the Issues and articles are freely available at
http://www.mwc-info.net/en/services/journal.htm

Contact Journal MCD
info@journalmcd.net for general inquiries MCD
funding@journalmcd.net for supporting the journal

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

MWC

contact@mwc-info.net for general inquiries

Postfach 2701
CH-8021 Zürich, Switzerland

Logement 11, Cité Andohaniato
Antananarivo 101, Madagascar

Jane Goodall Institut Schweiz

info@janegoodall.ch for general inquiries JGI

Jane Goodall Institute Schweiz
Postfach 2807
8033 Zürich
Switzerland