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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

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EDITORIAL

Rumblings in the forests heard loudly on the Web…

This, the first issue in 2010 of the Journal of Madagascar Conservation & Development (MCD), deals with illegal and destructive selective logging activities within the supposedly protected National Parks of Madagascar. Accounts of these multifaceted crimes and their impacts began circulating in the Malagasy forests and have since come to the attention of the global community courtesy of the World Wide Web.

In this issue, through the incredible efforts of numerous authors, reviewers, editors and translators, we are able to present a rich and diverse assemblage of voices which explore a wide range of angles within the broader context of illegal Malagasy logging.

It is our hope, that through the distribution of this issue, we can help to expose the ongoing, versatile range of injustices connected to this topic, help to secure remnant biodiversity in and around Madagascar's forests, and safeguard the human rights of its inhabitants.

At the core of this issue is the relatively recently arisen topic of Independent Forest Monitoring (IFM). An assemblage of scholars and conservationists directly involved with Madagascar's forests provide a detailed discourse on IFM, a subject that has far reaching consequences for the future of Malagasy forests. The central point of contention within the IFM framework is the illegal exploitation of rosewood, which threatens the ecological integrity of the forests and jeopardizes the short and long-term well being of numerous affected communities.

Thanks largely to the efforts of Hery Randriamalala and Zhou Liu, the patterns and mechanistic aspects of the illegal rosewood trade were initially brought to our attention. In addition, John Innes' essay for Spotlights raised awareness. Now, through the writings of (among others): Marie Jeanne Raherilalao, Jeanneney Rabearivony, Hubert Andriamaharoa, Thomas Baldauf and their collaborators, who provide compassionate accounts of ongoing activities in, around, and associated with the Malagasy forests, concern for this topic continues to grow.

It is our call to 'take the Zebu by the horns', both literally, and through words, and we encourage all readers to share with us their feedback. Initiating and maintaining an open dialogue permits fine tuning solutions based in constructive contribution and pertinent criticism. Through collaboration, we can all contribute to what we hope will be a comparatively bright and positive future for those who call this amazing island home, and the unique biodiversity found within.

Lucienne Wilmé, Editor-in-Chief

Patrick O. Waeber, Founder Editor

ÉDITORIAL

Les grondements de la brousse font des vagues sur la toile …

L'élaboration de ce premier numéro 2010 de Madagascar Conservation & Development est partie de murmures dans la brousse qui se sont amplifiés en traversant les forêts et les océans, ils ont retenti sur le www pour nous toucher et de partout nous entendons les grondements d'un peuple que certains qualifient de silencieux.

Jamais les rédacteurs de ce journal n'ont été tant sollicités et plus que jamais nous avons trouvé de l'aide pour vous livrer un numéro qui est le fruit du travail d'auteurs et de rapporteurs, d'éditeurs et de traducteurs qui veulent garder l'espoir de sauver les richesses de la Grande Île. De grands dossiers ont été ouverts à Madagascar au cours des derniers mois : ceux des droits de l'Homme, de la liberté d'expression, du développement durable, de la CITES, ou encore du Suivi Indépendant des Forêts (IFM), parmi tant d'autres.

Et bien sûr, nous reprenons dans ce numéro les principaux murmures de 2009 qui se sont à présent transformés en grondements ; ceux-là portent sur l'exploitation illégale des bois précieux qui menace l'intégrité des écosystèmes forestiers ainsi que la santé et l'avenir des habitants des régions concernées. Nous ne pouvons que féliciter Hery Randriamalala et Zhou Liu qui nous proposent leurs travaux scientifiques dûment documentés, rigoureux et brillamment analysés. Sous ce même dossier, John Innes nous dépeint un tableau local, avec ses spécificités, d'une scène qui s'inscrit sur la zone pantropicale du monde, voir au-delà.

Le journal continue de relayer les travaux des écologistes et vous invite à partager les passions de Marie Jeanne Raherilalao pour Nosy Hara ou encore celles de Jeanneney Rabearivony et de ses collaborateurs pour des sanctuaires du nord et de l'ouest, sans oublier Hubert Andriamaharoa ou Thomas Baldauf et leurs co-auteurs. Ces chercheurs nous présentent leurs travaux avec enthousiasme et nous montrent qu'ils sont les moteurs de la conservation de l'environnement ainsi que les formateurs, enseignants et mentors des générations futures.

Le suivi indépendant des forêts a été abordé en 2009 dans ce journal qui propose à présent d'en parler dans l'interview de ce numéro en sollicitant la participation de plusieurs spécialistes ; ce fut un réel succès et nous vous invitons vivement à poursuivre ce débat car il est loin d'être clos et ce sujet mérite que nous restions ouverts et que nous lui accordions toute l'importance qu'il mérite pour assurer l'avenir des forêts de Madagascar.

*Il nous appartient de prendre le zébu par les cornes, dans les faits et par les mots, et nous vous invitons à partager vos analyses et vos critiques, mais aussi à formuler des solutions afin que vous participiez à l'écriture de l'Histoire de la Grande Île. Les murmures auraient pû excuser des vociférations mais laissons les à l'*ankoay (Haliaeetus vociferoides)* qui agrémente le fonds sonore des littoraux occidentaux et poursuivons la publication de la conservation et du développement de Madagascar, afin de pouvoir formuler des solutions à mettre en œuvre pour sauver la vie et combattre les crimes.*

Lucienne Wilmé, Rédacteur en chef

Patrick O. Waeber, Rédacteur Fondateur

FOREWORD

Conserving locally, cheating globally? An obvious impasse

Not too surprisingly, there's a dearth of scientific data on corruption and environmental conservation. Or maybe I'm just a lousy 'Googler'. Either way, two years ago or so, I faced a challenge when looking for good, meaty, analytical work as the centerpiece for the pro bono dossier I was drafting for the French chapter of Transparency International. The theme of the dossier was 'Corruption and environment' and I was getting the invaluable assistance of none less than a former French minister of the environment, Corinne Lepage. I ended up quoting one of the few articles that I had downloaded, a rather old piece on Kenya and wildlife, good and relevant, but I was frustrated, because my swift and unpleasant search had, all in all, yielded droplets of what I knew was an ocean.

Indeed, corruption and environment do not go hand in hand, a simple linguistic remark, which banned me from any return trip to Madagascar, way back in 1990, during that 22nd trip of mine to what has now become Nosy Ména. Except for the frustration of not being able to look my old Malagasy friends in the eye and watch their children grow, I managed to have a life outside Madagascar and to survive, but my heart bleeds for the Malagasy and their present fate; corruption in environmental conservation is one of the many causes for the present chaos.

Correctly identified as one of the major biodiversity hotspots around the world, Madagascar is routinely wasting its most precious resources: Its inhabitants and their extraordinary talents. But another part of the waste is a waste of the natural resources. Properly utilized, they could help alleviate poverty and move the island and its dwellers into more sustainable and inclusive development. Alas, the roots of the evil, as predictable, is – again – money. Rather than getting a decent revenue from sustainable management of precious resources like rosewood, traffickers exploit humans and the ecosystem like shameful bloodsuckers.

I call upon the international community, and upon the Malagasy reformers, to come in force in this corruption-environment debate. I call upon all whose websites and glossy pamphlets promote transparency and good governance. There is no room for anymore complacency, hypocrisy and timidity. The time has come to take side and walk the talk. Let all those who disapprove of fraud and flaws come forward and support this issue of Madagascar Conservation & Development (MCD).

I praise the guts and rigor of the publishers, as well as the authors of the rosewood article Hery Randriamalala and Zhou Liu, and the other contributors to the Journal. If anything, using sunshine as a disinfectant and publishing what many know, but don't dare disseminate, are to be acknowledged with gratitude. Yes, conservation in Madagascar is far from perfect, but the baby should not be thrown out with the bath water. It is the pride of MCD to point the finger in the right direction and denounce those who market human exploitation and degrade natural resources for a huge and short-term profit. Let this be the beginning of a new era, with the support of large conservation non-governmental organizations, whose basic long-term interest lies in more transparency and better governance, a new era during which major environmental conservation issues are not swept under the carpet, but, on the contrary, brought to shining light for the good of the average Malagasy and their kin.

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PRÉFACE

Conserver localement, tricher globalement ? Droit dans le mur

Il semble exister une réelle pénurie de données scientifiques portant sur la corruption dans le domaine de la conservation de l'environnement. Ou peut être ne suis-je pas assez bon 'Googleur'. Toujours est-il, qu'il y a environ deux ans, lorsque je rédigeais l'article principal du dossier pro bono (qui représentait une analyse assez détaillée) pour le compte du chapitre français de Transparency International, je me suis trouvé face à un problème épineux. Le thème du dossier était 'Corruption et environnement' et j'avais l'aide une des incontournables spécialistes et pas moins célèbre ancien ministre de l'environnement Français, Corinne Lepage. J'ai fini par citer un des articles que j'avais téléchargé, une contribution assez ancienne sur la faune du Kenya, pertinente et de qualité dois-je reconnaître, mais je restais sur ma faim après cette recherche pour le moins 'rapide et grossière'. Pour cause, ce que je rapportais comparativement à ce que je savais n'était qu'une goutte d'eau dans un océan.

Corruption et environnement ne riment pas, simple remarque linguistique, qui fit de moi une persona non grata *à Madagascar ; mon 22e et dernier voyage à Madagascar remonte à 1990, en ce qui est devenu Nosy Ména. Malgré la frustration de ne pas pouvoir regarder mes anciens amis Malgaches dans les yeux et de ne pas voir leurs enfants grandir, j'ai réussi à faire ma vie en dehors de ce pays et à survivre, mais le destin actuel des Malgaches me fend le cœur ; la corruption qui règne au sein de la conservation de l'environnement est l'une des principales causes du chaos actuel.*

Reconnue comme un des principaux centres de biodiversité à l'échelle mondiale, Madagascar gaspille systématiquement ses ressources les plus précieuses que sont ses habitants et leurs extraordinaires talents. À ce gâchis humain s'ajoute un gaspillage des ressources naturelles. Judicieusement utilisées, elles devraient aider à réduire la pauvreté et conduire l'île et ses habitants vers un développement plus durable et plus inclusif. Hélas, la mère de ces maux, comme on pouvait s'y attendre, est – une fois de plus – l'argent. Plutôt que de dégager un revenu *décent par le biais d'une gestion pérenne des ressources précieuses telle que le bois de rose, les trafiquants exploitent les humains et l'écosystème comme des sangsues.*

J'en appelle à la communauté internationale et aux réformateurs Malgaches, afin qu'ils entrent dans le débat et prennent position contre la corruption dans le domaine de l'environnement. J'en appelle à tous ceux dont les sites Web et les brochures sur papier glacé appellent à la transparence et à une meilleure gouvernance. Qu'on en finisse avec la tolérance, l'hypocrisie et la timidité. Le temps est venu de choisir son camp et de pratiquer ce que l'on prêche. Que celles et ceux qui désapprouvent la fraude se lèvent et viennent soutenir ce numéro de Madagascar Conservation & Development (MCD).

Je loue le courage des éditeurs, des auteurs de l'article sur le bois de rose Hery Randriamalala et Zhou Liu, et des autres collaborateurs du journal. Si beaucoup le savent, ce n'est pas pour autant qu'ils osent le publier et le diffuser, il nous faut montrer notre reconnaissance à l'endroit de ceux qui agissent. Il est vrai que la conservation à Madagascar est loin d'être parfaite, cependant, ne jetons pas le bébé avec l'eau du bain. C'est tout à l'honneur de MCD de montrer du doigt la direction à suivre et de dénoncer ceux qui exploitent la misère humaine et la dégradation des ressources naturelles en recherchant des profits énormes et rapides. Promouvons le commencement d'une nouvelle ère, avec le soutien des grandes ONG environnementales, dont l'intérêt à long terme est la transparence et une meilleure gouvernance. Une nouvelle ère dans laquelle les principaux problèmes de la conservation de l'environnement ne sera pas mise à l'écart, mais au contraire, mise à nue pour le grand bien du simple citoyen de Madagascar et de sa famille.

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SPOTLIGHTS

Madagascar rosewood, illegal logging and the tropical timber trade

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ABSTRACT

Although deforestation rates in the tropics are reportedly slowing, the loss of both forest area and forest quality remains a significant issue for many countries. This is particularly true of Madagascar, where recent government instability has enabled a significant increase in the incidence of illegal logging of *Dalbergia* species from National Parks such as Marojejy and Masoala. The logs are exported with relative ease as export permits are being made available. While attempts have been made to improve the management of tropical forests, in 2005, the International Tropical Timber Organization considered that only 7 % of tropical production forests were being managed sustainably. Given the challenges associated with halting illegal logging at source, emphasis has shifted to the control of the trade in forest products. The Convention on the International Trade in Endangered Species provides a mechanism to restrict such trade, but the Madagascan *Dalbergia* species are not listed. In the USA, the recent amendments to the 'Lacey Act' could provide a significant disincentive to the import of illegally logged wood products, but it remains to be seen whether this Act can be enforced effectively.

RÉSUMÉ

Bien que les taux de déboisement sous les tropiques seraient à la basse, il n'en demeure pas moins que la perte de la couverture forestière et de la qualité des forêts restent des sujets sensibles pour de nombreux pays. Cela s'est avéré d'autant plus vrai à Madagascar que de récents troubles politiques ont été accompagnés par une augmentation significative de l'exploitation illicite de bois précieux, dont les bois de rose et les palissandres (*Dalbergia* spp.) dans les parcs nationaux comme ceux de Marojejy ou de Masoala. Les bois sont exportés assez facilement avec la délivrance de permis d'exportation dans un cadre législatif changeant. Dans le monde, il y a bien eu des essais d'amélioration de la gestion des forêts tropicales mais en 2005, l'Organisation internationale des bois tropicaux considérait que seulement 7 % des produits sylvicoles issus des forêts tropicales étaient exploités de manière pérenne. Compte tenu de la difficulté à s'attaquer aux sources de l'exploitation illégale pour y mettre un terme, une attention particulière a été portée sur le contrôle du commerce des produits forestiers. La convention sur le commerce international des espèces de faune et de flore sauvages menacées d'extinction connue par son sigle CITES constitue un mécanisme permettant de limiter un tel commerce mais les espèces malgaches du genre *Dalbergia* pour les bois de rose et les palissandres ou *Diospyros* pour les ébènes ne figurent pas sur les listes de la CITES. Aux États-Unis, le nouvel amendement au 'Lacey Act' pourrait permettre de freiner de manière significative l'importation de produits forestiers exploités illégalement mais il faut voir si cette Loi pourra effectivement être imposée.

KEYWORDS: Rosewood, *Dalbergia*, illegal logging, World Heritage Convention, CITES.
MOTS CLEFS : bois de rose, *Dalbergia,* exploitation forestière illégale, Convention du Patrimoine Mondial, CITES.

DEFORESTATION AND GOVERNANCE IN THE TROPICS

Since the threat of an embargo on tropical forest products in the 1980s, considerable attention has been given to efforts being made to stop deforestation in the tropics. Between 2000 and 2010, 3.4 million ha of forest in Africa and four million ha of forest in South America (including some temperate forest) were converted to other forms of land use (FAO 2010). Although some have suggested that the latest figures from FAO suggest that rates of loss of tropical forests are slowing, the long-term data from the UN Food and Agriculture Organization (FAO 2009) suggest that the rates have changed little since the early 1980s. Many tropical countries have enacted legislation to try and halt deforestation, but the flow of logs has continued, even from countries where all native forests are, in theory, protected. In such countries, ineffective enforcement or even the active collusion of government authorities have enabled illegal logging to continue and exports to take place. In some cases, including Madagascar, unstable political conditions have provided the opportunity for illegal logging to proliferate, and insecure governments focused on short-term priorities have often facilitated the logging.

Despite the numerous fora discussing illegal logging and other topics of interest to the international forest policy community over the past 25 years, little agreement has been reached over actions to deal with illegal logging, reduce deforestation or increase the proportion of the world's forests that are sustainably managed (Humphreys 2006). A 2006 report by the International Tropical Timber Organization (ITTO 2006) indicated that only 7 % of the 353 million ha of natural production forest in its producer member countries were sustainably managed. There is some debate over whether such figures actually represent sustainable management, as the presence of a management plan does not necessarily reflect whether or not a forest is being managed sustainably (Cerutti et al. 2008, Nasi and Frost 2009). The FAO has attempted to gather better information on this, but in their latest assessment, no response was obtained from countries representing 38 % of the global forest area, so no accurate global figures can be reported (FAO 2010).

Some progress is evident amongst the regional 'Forest Law, Enforcement, and Governance' groups, and some important bilateral initiatives have emerged, especially as a result of the EU Action Plan for Forest Law Enforcement, Governance and Trade. Government procurement policies in consumer countries have emerged as a potential means by which the demand for illegally-sourced wood could be curbed, and an increasing number of countries have adopted these (Simula 2010). However, the extent of enforcement is unclear. Amongst the potential market-based mechanisms, certification was long intended to be a tool that would reward those in the tropics managing their forests sustainably and to separate products derived from well-managed forests from the products of deforestation (Bass et al. 2001), but uptake of this procedure has been disappointingly slow. Recent evidence suggests that even in certified forests, illegal logging is still occurring, suggesting significant problems with the auditing process (Nsoh 2009). In the following, I concentrate on one aspect of the international timber trade, illegal logging. In particular, I focus on the trade in rosewood originating from Madagascar.

ILLEGAL LOGGING

There are many difficulties with the concept of illegal logging, not least its definition (Tacconi 2007, Brown et al. 2008). However, many take a fairly straightforward approach and define it as the harvest, transport, sale or purchase of timber in contravention to national laws. As such it includes timber taken without a license, timber taken from protected areas, timber stolen from private property, timber taken without paying the correct stumpage and a range of other forms of abuse. The 'U.S. Lacey Act', to be enforceable, has provided the definitions to be used in the USA. Modified to be specific to logging, the definition of an illegally sourced product includes the theft of logs, the taking of logs from an officially protected area, the taking of logs from other types of 'officially designated' areas recognized by a country's laws and regulations, the taking of logs without, or contrary to, the required authorization, the failure to pay appropriate royalties, taxes or fees associated with the log's harvest, transport or commerce, and the contravening of laws governing export or trans-shipment. For a contravention of the Lacey Act to occur, a person must trade this illegally sourced product in U.S. interstate or foreign commerce. This requires an offender to "import, export, transport, sell, receive, acquire, or purchase" the product. Much will depend on the efficacy of the mandatory species labelling, which it will be an offence to violate, but checking that the wood really does come from a specific species will be extremely difficult without detailed laboratory testing.

The 2008 amendment to the Lacey Act has provisions for prosecutions through either criminal or civil action, or through forfeiture. Civil penalties of up to $US 10,000 are being applied to any party who, in exercising due care, could reasonably have been expected to know that trade in the plant or wildlife in question was illegal. Civil penalties are also applied to any party that knowingly commits an offence associated with false labelling or knowingly violates the declaration requirements. The size of the penalty depends on the nature, circumstances, extent, and gravity of the offence, and the culpability and ability to pay of the offender. Forfeiture also occurs in civil cases. Any illegal timber or products made from illegal timber brought into the U.S. may be seized whether or not the person involved knew about the illegal nature of the product.

Criminal prosecutions under the Lacey Act are divided into misdemeanours and felonies. The division is based on the knowledge of the offender and the intent (*mens rea*) to commit a crime. The crime is classed a misdemeanour if the government determines that the offender should have known that the handling of the goods was illegal. In such cases, the offender is expected to have exercised due care in determining the potential illegality of the goods. Individuals are subject to fines of up to $US 100,000 and organizations to fines of up to $US 200,000 and / or imprisonment for up to one year. Felonies occur when the government can show that the offender knew, or was generally aware, that handling of the product was illegal. The value of the product must exceed $US 350. Penalties include prison sentences of up to five years, and fines of up to $US 250,000 (individuals) or $US 500,000 (corporations).

An often-used excuse to justify commerce in illegally sourced materials is that if they are purchased on the open market, it is the responsibility of the source country to police its own territories. In some cases, this argument is reinforced by the logs passing through another country – the forestry equivalent of money-laundering. For example, in the case of Madagascar, many rosewood logs shipped from ports such as Vohémar and Toamasina pass through the ports of Mayotte or Mauritius (Barrett et al. 2010), where they are then sold on to the European Union, China and elsewhere (Global Witness and Environmental Investigation Agency 2009). Within an international context, law enforcement is essentially a national responsibility. It is reiterated in Principle 3 of the Convention on Biological Diversity "States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control to not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction". However, under the Lacey Act, it will be an offence to trade in illegally-sourced products, even when the authorities of the source country have knowingly or unknowingly allowed the trade to occur.

A key issue is enforcement. On March 24, 2010, the transitional authority in Madagascar issued a decree prohibiting all exports of rosewood and other precious timber for a period of two to five years (decree no. 2010-141). However, it appears that the decree has not been completely endorsed by the government, enabling logging in national parks, such as Masoala National Park, to continue (Bohannon 2010). In addition, the current decree allows rosewood exports to occur with a ministerial order. This has created considerable uncertainty which, combined with the local difficulties of enforcement, have created ideal conditions for illegal logging to flourish.

LOGGING BANS AND CITES

Trade in endangered species is officially controlled through the Convention on International Trade in Endangered Species (CITES). However, only one species of rosewood, the Brazilian rosewood (*Dalbergia nigra*), is listed under Appendix I of CITES, indicating a ban on all international trade in the species. Two further species (*D. retusa* and *D. stevensonii*) have their Guatemalan populations listed under Appendix III, which indicates that a party has requested cooperation from other countries to prevent unsustainable or illegal harvesting. Some of the demand for rosewood from Madagascar can be directly attributed to the shortage of supply of Brazilian rosewood, an unintended consequence of the CITES ban in its trading. With 48 species of rosewood (*Dalbergia* spp.) present in Madagascar (Bosser and Rabevohitra 1996, 2005, Du Puy et al. 2002), any separation of logs belonging to listed species from those that are unlisted will be difficult (Bohannon 2010). Consequently, a listing under CITES will need to cover all the *Dalbergia* species present in Madagascar if it is to be enforceable. Other species are also threatened, including the ebonies (*Diospyros* spp.). With the ebonies, it is even uncertain how many species there are in Madagascar, with many specimens awaiting formal identification and naming.

CITES has not always been an effective way to ensure the conservation of trees. A good example is provided by broadleaf mahogany (*Swietenia macrophylla*). This species is widely distributed throughout the Neotropics, but has been placed on the IUCN Red List of Threatened Species, where it is classed as 'vulnerable', meaning that it is considered as facing a high risk of extinction in the wild in the near future. The species was initially listed under Appendix III by Costa Rica in 1995, but other countries did not follow suit for several years, meaning that imports from some countries were legal, while those from Costa Rica required special certificates. This resulted in substantial difficulties of enforcement (CITES Management Authority of the USA 2001, TRAFFIC 2002). It was moved to Appendix II of CITES in 2003, a classification that restricts exports, but still enables export certificates to be issued if it can be demonstrated that "the anticipated impact of current or proposed harvests on species' population status will be non-detrimental to the species in its role in the ecosystem" (CITES 2009). No import certificates are required if the authorities of the importing country are satisfied that trade in the species will not be detrimental to the survival of the species in the wild (which seems inconsistent with the IUCN listing). Importing countries must also be satisfied that the wood has been obtained legally. Individual countries have experienced many problems in managing the logging of the species and in restricting exports (CITES 2008a, b), and the ongoing debate over this species demonstrates just how difficult enforcement of trade restrictions on timber species can be.

The history of the ban on rosewood exports is interesting. A qualified ban was introduced by government decree in 2000 (decree no. 11832 / 2000). Despite the ban, there has been a steady amount of logging and export, normally through ministerial permits (Schuurman and Lowry 2009). This was reversed on 28 January 2009, when a new decree authorized rosewood exports. With a military coup occurring in March 2009, the new government allowed exports to continue and it was only with the March 2010 decree that logging of rosewood was again banned. However, as mentioned above, it remains possible to get a ministerial decree to enable the export of rosewood from Madagascar. The lifting of the ban enabled massive logging operations to take place, much occurring in the Marojejy and Masoala National Parks (Schuurman and Lowry 2009, Wilmé et al. 2009a). Increased logging also took place in Makira Natural Park, although this classification does allow some logging to occur under normal circumstances. The first exports occurred as early as April 2009 (Débois 2009).

In trying to regulate any trade, an important problem will be the difficulty of identifying individual species. Even labelling the wood 'Madagascar rosewood' will not necessarily help since in the timber trade, this term is used ambiguously. For example, the website of Winwood Products (a UK company) states "Madagascar Rosewood is also called Kali, Kararo, Landojan, Landosan M'boul, Mukali, Mukangu, Muna, N'Kali, osan, Tanganyika Nuss and Tutu. The species occur from Guinea to Ethiopia, and is also found in Zambia and Gabon" (Winwood 2010). A quick internet search revealed numerous rosewood items for sale in the U.S. made from Madagascar rosewood, particularly acoustic guitars, as well as lumber (from *Dalbergia baroni*, known as 'palissandre'). The difficulties of enforcing any ban are currently being tested: The Nashville plant of Gibson Guitar Corporation is under investigation by the U.S. Fish and Wildlife Service for violations of the Lacey Act, allegedly for the use of Madagascar rosewood. This is the first investigation of a case involving wood made under the 2008 revision of the Lacey Act. Gibson Guitar has previously been recognized for its recognition of the problems associated with illegal logging, and has been sourcing mahogany from legal, certified sources in Honduras and Guatemala (Rainforest Alliance 2010). The U.S. Fish and Wildlife Service will have to demonstrate that illegalities involving other wood have occurred, providing an interesting test case of direct relevance to the trade in Madagascar rosewood. As Gibson Guitar has a chain of custody certificate issued by the Forest Stewardship Council (FSC), and has been subject to annual inspections by the FSC, the case also demonstrates the potential difficulties associated with the voluntary forms of wood product regulation.

While there may be difficulty in identifying the species that logs in a port are derived from, or the sources of timber at a manufacturing facility, there is a sound understanding of who in Madagascar is cutting the rosewood, who is selling it, who is transporting it and who is buying it (Wilmé et al. 2009a). This contrasts with many other illegal logging situations around the world, where the attribution of responsibility is much more complex. The potential financial income from the trade in illegal rosewood is substantial, and the 1,137 container-loads known to have been exported in 2009 would have sold for more than $US 200 million (Wilmé et al. 2009a). This presents problems for the Madagascar authorities, as there are substantial stockpiles of illegally harvested rosewood logs (Wilmé et al. 2009b).

A major destination for tropical hardwoods is China. Madagascar rosewood is no exception, and there is a high demand for this product for the manufacture of traditional Chinese furniture (Wilmé et al. 2009a). Much of this is sold within China, but some is exported to the USA, and will be subject to the restrictions imposed by the Lacey Act. China is currently in the process of introducing certification programs that have clear chain of custody requirements, but if North America is a good example, very little effort will be made to ensure that furniture products come from legal and sustainably managed (i.e., certified) sources. However, there are also a range of other destinations for Madagascar rosewood, including North America and Europe.

THE FUTURE

The ongoing problems associated with the logging and export of rosewood from Madagascar has illustrated the many challenges faced by those attempting to put a halt to illegal logging and ensure the long-term survival of individual tree species. Clearly, designating a reserve is insufficient if there is no capacity or will to enforce the reserve. Similarly, designating a species as protected will also fail if there is no enforcement. The international forest policy community has been ineffective in both stopping deforestation and encouraging the more sustainable management of forests. International bodies such as the Food and Agriculture Organization of the United Nations do not have the power to ensure enforcement, and its reliance of contributions from individual member states severely limits its ability to monitor what is occurring. The International Tropical Timber Organization could play a greater role, but so far has not done so, again partly because of its organizational structure. As a first step, Madagascar needs to have its rosewood species listed by the Convention on International Trade in Endangered Species.

While governmental and inter-governmental processes can be of value, there is an urgent need for the independent monitoring of forests. To a certain extent, this is being done on a voluntary basis through the certification movement. However, the case of Gibson Guitar Corp. described above will demonstrate just how effective this is. There is a strong case for a more rigorous, independent process of forest monitoring with some form of legal powers. Such processes are extremely difficult to implement when they impinge on national sovereignty, as demonstrated by the failure to establish a legally-binding global forest convention to date. Organizations such as the World Resources Institute in Washington D. C. may be a suitable alternative, provided that they can demonstrate a non-partisan approach to their work.

For Madagascar, an important step would be for the government of Madagascar to request that Marojejy and Masaola National Parks, both of which are UNESCO World Heritage sites, be included in the 'list of World Heritage in danger'. This would be in accordance with Article 11(4) of the 'Convention Concerning the Protection of the World Cultural and Natural Heritage'. This convention has the capability of forming an effective means to ensure the protection of important natural forests worldwide, but so far has not been very effective in doing so. Greater international attention needs to be given to this and other conventions, and mechanisms to ensure that signatory countries respect them are needed.

National mechanisms will only occur when there is a political will for the actions. At present, the government of Madagascar has not indicated that it is willing to shut down the export of rosewood, creating the opportunity for the continued degradation of forests where rosewood occurs, including those supposedly protected in reserves. Clearly, pressure needs to be brought to bear on the Madagascar government so that the long-term benefits of forest conservation will become more apparent.

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Rosewood of Madagascar: Between democracy and conservation

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ABSTRACT

In 2009 an estimated 52,000 tonnes of precious wood from ca. 100,000 rosewood and ebony trees was logged in north-east Madagascar, one third originating from Marojejy National Park and its environs, the remainder from in and around Masoala National Park. At least 500,000 additional trees and many miles of vines were cut to make rafts to transport the heavy ebony and rosewood logs. Approximately 36,700 tonnes were shipped in 1,187 containers, almost all to China, for a total export sale price estimated at $ US 220 million. In the SAVA region, members of the timber syndicate pocketed 76 % of this whereas the State collected just $ US 15.3 million. Of the three main companies that transported rosewood from Vohemar, Delmas benefited most; three banks also facilitated the illegal timber trade. Fraud is perpetrated by the syndicate and government administrators along every step in Madagascar's precious timber trade in a coordinated effort to maximize profit and minimize taxes and fines. Poor governance and a lack of clarity in forest regulation have facilitated timber trafficking and undermined judicial control; during at least three periods (1992, 2006 and 2009-2010) escalation of rosewood exportation has been facilitated by government decrees issued prior to elections or during difficult political times, in each instance accompanied by 'exceptional' government orders allowing a few powerful operators to export massive quantities of wood – all part of a carefully orchestrated cycle. The near-silence of donors and NGOs is linked to their loss of influence following suspension of all but humanitarian aid since 17 March 2009.

RÉSUMÉ

La campagne 2009 de bois précieux à Madagascar représente au minimum 52 000 tonnes de bois précieux abattu, venant de 100 000 arbres de bois de rose et d'ébène dont plus de 60 000 situés dans les aires protégées, ce qui représente au minimum 4 000 hectares de parc et 10 000 hectares de forêt intacte non-classée ayant fait l'objet d'une coupe sélective. Le bois de rose provient de la région du Marojejy pour un tiers, et de celle du Masoala pour les deux autres tiers. Plus de 500 000 autres arbres et des dizaines de milliers de lianes ont été coupées pour faciliter le transport du bois précieux. Environ 36 700 tonnes de bois précieux ont été exportées dans 1 187 conteneurs à destination de la Chine (50 tonnes d'ébène vers l'Allemagne) pour un prix de vente estimé à 220 millions de dollars, dont près de la moitié est réalisée à l'exportation au départ de Vohémar dans la SAVA. Les 22 exportateurs ont réalisé 76 % de bénéfice sur ce chiffre. Le premier bénéficiaire individuel de ces exportations est l'État malgache (15,3 millions de dollars de recettes). La fraude pour l'ensemble de la filière est évaluée à 4,6 millions de dollars. Le montant des devises non rapatriées pourrait s'élever à 52 millions de dollars. Alors que la réglementation prévoyait 13 exportateurs agréés, 23 ont exporté. Des trois compagnies maritimes qui ont participé à cette activité, Delmas est celle qui en a le plus profité. Trois banques ont soutenu les exportations.

À au moins trois reprises (1992, 2006 et 2009-2010), l'exploitation du bois de rose a été facilitée par le pouvoir peu avant des élections importantes. L'impact sur les aires protégées est un amoindrissement de leur biodiversité, une fragilisation du milieu aux atteintes naturelles ou humaines. La campagne de coupe de bois de rose est en partie responsable du recul de la fréquentation touristique (-56 %) en 2009. Cette filière est un commerce inéquitable : la partie chinoise touche 25 fois plus que la partie malgache et 357 fois plus que les villageois de la forêt. Le chaos de la réglementation forestière a facilité ce trafic. La responsabilité de la classe dirigeante dans la campagne 2009 est totale. Le quasi-silence des bailleurs de fonds est la conséquence de la suspension de toute aide autre qu'humanitaire après le 17 mars 2009, ce qui leur a enlevé toute influence. Depuis l'interdiction de coupe sur le territoire chinois, en 1998, les importations de bois en provenance des pays tropicaux et tempérés ont été multipliées par six. La Chine protège donc ses propres forêts en « exportant de la déforestation ».

KEYWORDS: Illegal logging, *Dalbergia*, corruption, governance, China.
MOTS CLEFS : exploitation forestière illégale*,* *Dalbergia*, corruption, gouvernance, Chine.

INTRODUCTION

The oldest recorded rosewood exploitation in Madagascar dates to 1899 (Botokely 1902): Just three years after colonization, a timber trader named Mr Cayeux sourced rosewood at Ratsiharanana, south of Antalaha, and exported 50 tonnes per month, while the company Vinany Be, operating farther south on the Masoala peninsula, exported far less – a total of 200 tonnes during 1900 and 1901.

Alarming and uncontrolled trade in rosewood led to the Ministry of Water and Forests (MEF; for clarity 'MEF' is used to refer to the Ministry of Water and Forests, the Ministry of Environment and Forests, and any of the other names applied at various times to this Ministry) and the Ministry of Trade to issue a decree (11932 / 2000) prohibiting any export of unprocessed rosewood for three years (Stasse 2002). Issued on 20 November 2000, Order No. 12704 / 2000 called for a halt to extraction of timber in all designated protected areas as well as areas on their periphery. Furthermore, according to Article 4 of this order, no exceptions were to be granted. It is estimated that up to 87 % of logging of all types of wood in the eastern coastal region is illegal (Eaux et Forêts, cited by Brodbeck 1999) and that 60 % of rosewood logging is illegal (Stasse 2002). Precious timber harvested in the SAVA region before 14 September 2006 was done so illegally as permits were not in accordance with applicable laws and regulations, and timber harvested thereafter is illegal under Interministerial Order No. 16030-2006 (GW and EIA 2009).

The precious timber industry is cunningly organized: International trade is frequently orchestrated by established traders holding an official export agreement or by the individuals and companies exploiting the forests. They pay independent woodcutters (i.e., local villagers or farmers) to fell trees, both within and outside officially approved lots, or in areas where the authorities have issued permits for logging companies to exploit timber and other forest products. But villagers cut trees where they are easiest to access and drag to transport points, regardless of whether they are in the delineated forest lots or outside the borders of protected areas (such as Masoala National Park), and after years of extensive exploitation, larger trees of rosewood (*Dalbergia* spp.) have become rare (Stasse 2002).

Working under an operating licence issued to a trader or timber company, woodcutters operate freely throughout the forest, with or without approval. Wood originating from outside designated lots is thus mixed in with legally sourced timber. The logging companies pay the collectors, who mark logs with the official forest hammer of the company, thereby legalizing the wood (Stasse 2002).

Order No. 13855 / 2001 issued by the MEF on 13 November 2001 states in Article 30, paragraph 3, that "when a tree is felled and cut into logs, the ends must be marked with a hammer or paint to indicate the locality where the tree was felled". Article 37 states that "any timber removed from a site must be cut at each end and must contain information about the forestry operator and the officials of the Forestry Administration, which will officially receive the product". According to Decree No. 98 / 782 of 16 September 1998, under Law 97 / 107 of 08 August 1997 (GW and EIA 2009), all products not conforming to the above regulations are considered illegal and should be confiscated.

In March 2009, the National Parks of the SAVA region were invaded by thousands of woodcutters during a period of intense, illegal logging activity that lasted at least six to eight weeks. The woodcutters removed previously cut trees and felled more trees. In north-eastern Madagascar, rosewood occurs primarily within and adjacent to Marojejy, Masoala and Mananara National Parks. Valuable timber species are under severe pressure in all these forests, regardless of whether they fall within a protected area. Frenzied felling of rosewood was observed in the north-eastern sector of Masoala National Park in 2009. The transport of logs to Antalaha was conducted openly on stretches of road both north and south of town controlled by gendarmes, a fact that reflects a serious deterioration of the law and active collaboration between the law enforcement agencies and illegal timber traders. A lack of supervision and control by the Forestry Administration over cutting, transportation and storage of rosewood is cause for grave concern (GW and EIA 2009).

The year 2009 was exceptional for the rosewood industry in Madagascar, which, between political turmoil, abundant lobbying and media campaigning, has had unprecedented international exposure. In this article we aim to analyze the rosewood industry in Madagascar in the context of patterns of political events, government decrees, and illegal logging activities. We will outline the processes and mechanisms of the rosewood trade, from the sourcing of the timber to the local and regional exporters, through shipping and exporting, to the buyers and end users of the timber.

METHODOLOGY

DATA COMPILATION. Our survey was conducted over a period of one year, starting in February 2009 as intense logging began in the protected areas of the SAVA region. Participants and observers from all sectors of the industry, alarmed by the magnitude of what was happening, provided us with documents including permits, minutes, statements and contracts, issued amongst others by officials from MEF, the Customs and Justice services, banks, shipping companies and exporters.

We conducted a survey by interviewing people involved in the exploitation and trade of rosewood, including public officers, woodcutters, port agents, travellers who visited the region, residents of the towns of Andapa, Vohemar, Sambava, Antalaha, Maroantsetra and Mananara, passengers on ships sailing between Toamasina and Antalaha, tourist guides and Madagascar National Parks (MNP) agents based at Marojejy and Masoala, tourists and journalists returning from the parks, bank employees, and two exporters based in Antalaha. For safety reasons, interviewees who have requested anonymity are quoted as 'anonymous'. Mention a company's name indicates that we are in possession of documents to support statements. Where we are not in direct possession of relevant documentation, we cite the facts, but do not list names of the individuals or companies in question.

PARAMETERS AND DEFINITIONS. The parameters used in this article are presented in Table 1. This article uses several key terms, defined as follows:

- Exporter (traders): Any person or company with consent (granted by the MEF) to export precious timber from Madagascar.
- Buyer: Any person or company buying precious timber from Madagascar. The common practice is that a buyer visits the region to meet an exporter, examine the quality of the wood, check its weight and accept the mode of payment requested by the exporter.
- Bank: A financial institution which advances funds for harvesting wood and domiciles an export operation (obligatory under Malagasy regulations as a bank must ensure that the total amount on the invoice in hard currency is repatriated within a period of three months, after which the bank has another three months to exchange 90 % of the hard currency with the Central Bank).

TABLE 1. Parameters used in calculations (partly based on GW and EIA 2009, Stasse 2002, Parant et al. 1985; rate of exchange used for Malagasy Ariary = MGA: $ US1.00 = MGA 2,000)

Parameters	Unit	Value
Weight, length, volumes		
External dimensions of a 20 Ft container	m	6*2.4*2.6
External dimensions of a 40 Ft container	m	12.2*2.4*2.6
Volume of a 20 Ft container	m^3	33
Volume of a 40 Ft container	m^3	67
Maximum net weight of a 20 Ft container in Vohemar (estimation based on the limitation of the lifting equipment at the port of Vohemar until February 2010)	tonnes	20
Maximum net weight of a 20 Ft container in Toamasina (for a wood density of ca. 1.02)	tonnes	33
Maximum net weight of a 40 Ft container in Toamasina	tonnes	67
Transportation costs		
Purchase and transportation of one ton of rosewood from the forest to Antalaha	$ US	420
Transportation of one container from Antalaha to Vohemar	$ US	750
Container packing per container	$ US	20
Dock work for one container in Vohemar	$ US	250
Transportation of one 20 Ft container to Hong Kong by UAFL	$ US	1,875
Transportation of one 20 Ft container to Hong Kong by Delmas	$ US	2,030
Transportation of one 40 Ft container to Hong Kong by Safmarine (estimation)	$ US	3,500
Taxes		
Collection fee (*redevance à la collecte*) per kg from 28 I 2009 onwards (Interministerial order N. 003/2009)	$ US	0.05
Collection fee per kg from 21 IX 2009 onwards (Interministerial order N. 38244/2009)	$ US	0.25
Exportation fee for semi crafted wood from 2004 onwards (Interministerial order N. 17939/2004) on FOB price (Free On Board / Freight On Board - for a price which includes goods plus the services of loading those goods onto some vehicle or vessel at a named location)	FOB price	4.00 %
Exportation fee for crafted wood from 2004 onwards	FOB price	1.50 %
Exportation fee for all types of wood from 21 IX 2009 onwards (Interministerial order N. 003/2009)	FOB price	5.00 %
Fine per container from 30 July 2009 onwards (Decision N. 338/09/MEF/MI)	$ US	36,000
Selling price of rosewood		
Real selling price per kg of rosewood in logs or lumber (*plaquettes*); The FOB selling prices in March 2009 in Vohemar varied between five and six $ US per kg for class one timber. These prices reached $ US 10 to 11 in early 2009. The FOB price for class two wood was $ US 3-4 per kg. To simplify calculations, we considered a mean price of $ US 6 per kg regardless of the monthly variation and classes	$ US	6
Banks		
Mean domiciliation cost per bill	$ US	15
Foreign exchange commission		0.50 %
Forestry		
Mean density of rosewood		1.02
Mean density of ebony		1.40
Mean weight of a rosewood log with a diameter of 35 cm and a length of 2 m	kg	196
Number of logs obtained from a tree (min – max)		2 - 4
Number of lumbers within a log (min – max) (Sentence N. 2617 passed on 28 July 2008 at Antalaha court)		3 - 5
Number of rosewood trees per ha in protected areas (min – max)		3 - 5

- Shipping company: Any company that ships containers of precious wood for export from Madagascar. These companies make regular runs to Mayotte or Mauritius, where containers are gathered for shipping to their final destination.
- Tax: Charges levied on the exported precious timber. In addition to the forest fee / licence, which should indicate the quantity of wood that can be harvested in a given forest lot, the exporter must also pay a collection fee (currently $ US 0.25 / kg), an export fee (5 % of the FOB price) and a 'fine' of $ US 36,000 per container (Table 1).

RESULTS

QUANTITIES. Based on our survey and the parameters listed in Table 1, we calculated the total impact of the illegal logging within the SAVA and Analanjirofo regions for the year 2009, as presented in Table 2. In addition to the estimated 100,000 trees of rosewood (*Dalbergia* spp.) felled in these two regions, at least 500,000 additional trees (e.g., *Dombeya* spp.) were also cut to make rafts to float the heavy precious timber (on average five high buoyancy trees are required to float one rosewood or ebony log) and tens of thousands of vines have been cut to bind the rafts (GW and EIA 2009). Assuming that (i) timber stored in the region of Antalaha is from the neigh-

TABLE 2. Logging of precious timber in Madagascar during 2009.

	Unit	Total quantity	Exportation
Total weight	Tonnes	52,000	36,730
Total number of logs		300,000	187,600
Estimated number of trees		100,000	
Estimated area impacted	ha	4,000 – 10,000	
Number of beams exported			74,250
Number of containers			1,187
Selling price	$ US		220,000,000
Taxes ($ US 1.-- = MGA 2,000)	$ US		21,900,000

bouring Masoala Peninsula, and (ii) the wood stored between Sambava and Vohemar (excluding that currently stored in Vohemar awaiting export) originated from Marojejy and the banks of the Bemarivo River, we infer the following breakdown of the geographical origin of harvested timber: 64 % from Masoala NP, and 36 % from Marojejy NP and the Bemarivo watersheds.

The figures in Table 2 on the number of containers loaded with precious wood exported in 2009 are applicable to Vohemar and Toamasina. From March to September 2009, an average of one vessel per day left Maroantsetra and another from Mananara bound for Toamasina, accounting for the daily shipment of 50 tonnes of timber. After October 2009, the rate declined to one vessel per week, with two or three boats departing weekly from Antalaha. Stasse (2002) estimated that Toamasina has been the main port for the export of rosewood from Madagascar. A major litchi exporter shipped 300 containers of rosewood from there during this period (Toamasina port official pers. comm.). Given the number of shipments observed between Antalaha and Toamasina, we deduce that the 300 containers reportedly shipped from there were of the larger 40-foot size (totalling ca. 20,000 tonnes). Of the 36,700 tonnes exported, only 249 (0.7 %) were of ebony and the remainder of rosewood.

The time scale diagram in Figure 1 shows monthly rosewood trade activity at the port of Vohemar as compared with the publication of government notes and orders. Activity peaked in February - March 2009, while the central government was almost completely dysfunctional (Débois 2009).

In 2000 - 2001 and just prior to political turmoil in 2002, rosewood exports amounted to almost 5,000 tonnes annually, declining to almost nothing for 5 - 6 years, and increasing again starting in 2007 (when 2,385 tonnes were shipped). Exports then escalated to almost 14,000 tonnes in 2008 (prior to the current political turmoil) and during the exceptional activity of 2009 they increased further to more than 36,000 tonnes. The figures presented for 2007 and 2008 mostly pertain to rosewood seized by the state and sold by auction to a single buyer (Anonymous 2008a). In addition, the inventory of 03 June 2009 compiled by the Forestry Administration (concerning tonnage of precious timber shipped after that date from Vohemar along with various additional reports of stocks) shows a reserve of 15,600 tonnes awaiting export.

Undoubtedly there are many additional caches of precious timber remaining concealed in forests, buried on beaches, hidden in shallow ocean waters, submerged in rivers and in rice paddies, or stashed under houses and in covered depots (Débois 2009). As we are unable to estimate the tonnage of such caches, however, we have ignored them in our analyses and our results thus offer a conservative evaluation of the current situation.

PLAYERS IN THE ROSEWOOD TRADE. Exporters: Until September 2009, 13 exporters were involved in the rosewood trade, concentrated in Antalaha, a situation that changed significantly with the publication of Order No. 38244 / 2009 on 21 September 2009, which increased the total number of individuals or companies authorized to export precious timber to 23 between September and December 2009. This order was accompanied by noticeable encouragement for the creation of

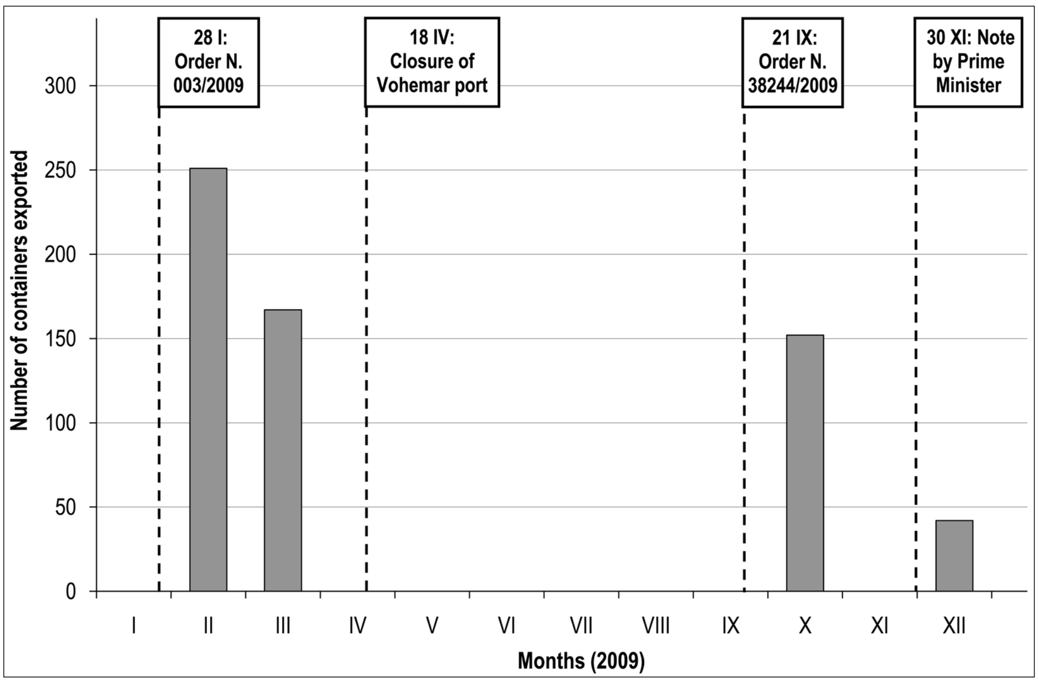

FIGURE 1. Timetable of monthly exports of precious wood from Vohemar in 2009.

new companies to export timber, not just from the SAVA region but also from the capital city of Antananarivo.

By multiplying the tonnage exported by each exporter by the estimated price received ($ US 6 / kg), and then deducting taxes and miscellaneous other charges, we have attempted to estimate the profit made by the exporters. The true profit obtained by the exporters is, however, likely significantly higher that what we have estimated because it appears that in many cases Chinese buyers rather than the exporters have paid the $ US 36,000 'fine' per container levied by the Administration since September 2009 (GW and EIA 2009). To put these numbers into perspective, we calculated the share received by the government (through taxes levied only in the SAVA, because those paid in Toamasina are very difficult to estimate – see below on fraud and fines) and the share going to the villagers (woodcutters and porters, estimating their number at 5,000). We used these figures to calculate the total revenue for the SAVA alone in 2009, which we estimated at $ US 92,517,500, with the State collecting a total of $ US 15,311,000 (16.5 %), the 22 exporters operating in the region pocketing more than $ US 70,734,000 (76.5 %, the three main exporters accounting for almost half of this, with just a little more than $ US 15,155,000 for Ets Ranjanoro, $ US 9,819,000 for Ste Thunam Roger et Cie. and $ US 8,863,000 for Laisoa Jean-Pierre) and the villagers receiving an average of just $ US 1,300 each (or 7.0 % of the total for the estimated 5,000 persons involved).

The three exporters who received the best return on their investment (i.e., net profit / gross profit) are Ets Ranjanoro (97 %), Laisoa Jean-Pierre (97 %) and Bezokiny Christian Claude (96 %). Probably because they are the most experienced companies in the business, they exported little or no timber after July 2009, the date on which the 'fines' were imposed. The three exporters who received the highest return per amount sold (profit / kg exported) are Laisoa Jean-Pierre ($ US 5.38 / kg), Ets Ranjanoro ($ US 5.35 / kg) and Bezokiny Christian Claude ($ US 5.28 / kg). The explanation is the same as for return on investment, although Ets Ranjanoro and Laisoa Jean-Pierre employed a method that differs from that used by other traders: They exported numerous squared logs in February and March 2009, thereby reducing empty space by packing the containers more efficiently, optimizing quantity per container and thus reducing cost per volume shipped.

Banks: Three local banks have supported the export of rosewood: Bank of Africa (BOA), BNI-Crédit Lyonnais (BNI-CL), and BFV-Société Générale (BFV-SG). Note that BOA shareholders include the Agence Française de Développement (French Development Agency), the World Bank Group (through the International Finance Corporation), the Netherlands Development Finance Company, and the Banque Marocaine du Commerce Extérieur (Moroccan Bank of Foreign Trade).

Bank domiciliation: In order to control the compulsory repatriation of foreign currency to Madagascar, the Ministry of Finance requires bank certification that a local exporter has a foreign currency account in one of its branches. Certification is required for each separate transaction. Before wood can be shipped, exporters thus must pay for logging, transport and storage, and the banks provide them with necessary financial resources for this. Transactions with the 23 currently authorized exporters enabled the three banks to make profits of no less than the following amounts: BOA (ca. $ US 98,000), BNI-CL ($ US 32,000) and BFV-SG ($ US 22,000).

Shipping companies: The difficulties of land transport on and around the Masoala Peninsula, due to poor or nonexistent roads, stimulated domestic shipping by water as a means of moving harvested rosewood. The timber cut in the Mananara National Park and in Makira Natural Park, as well as in the southern part of Masoala, is primarily transported by boat to Toamasina, occasionally to Antalaha. Wood from the northern sector of Masoala is usually moved along trails to Antalaha, or sometimes by ship to Toamasina. Timber extracted from Marojejy is consistently transported by road to the ports of Vohemar or Antsiranana.

Three international shipping companies have transported containers of rosewood from three ports to Asia, as follows: (1) from Vohemar: UAFL and its subsidiary Spanfreight, Delmas (a subsidiary of the CMA-CGM group), and Safmarine; (2) from Toamasina: Delmas, Safmarine, and PIL Shipping; and (3) from Antsiranana: Delmas, Safmarine and MSC. Only UAFL, Safmarine and Delmas transported precious wood in 2009 from Vohemar. Based on the parameters indicated in Table 1, these companies had the following share (number of containers × fee per container): Delmas (ca. $ US 1,285,000), UAFL (ca. $ US 220,000) and Safmarine (ca. $ US 120,000).

Safmarine transported 32 40-foot containers in February and March 2009 from Toamasina (Safmarine to Schuurman In litt.), but the following month they elected to stop all shipment of precious timber from Madagascar for an indefinite period. UAFL was made aware in October 2009 of the origin and legally dubious nature of the timber they were transporting, as well as the environmental damage that the illicit logging industry causes (UAFL to Schuurman In litt.). They voluntarily stopped transporting rosewood after a final shipment on 30 October 2009 on board the Mauritius.

Buyers: In 2001, 98 % of precious timber exported from Madagascar went to China (Stasse 2002), and in 2009 the figure was almost 100 %, the sole exception being a small quantity of ebony sent to Germany and Mauritius. In 2005 China imported a total of 29.4 million m^3 of timber as logs, ca. two thirds of which originated from Siberia and 25 % (7.4 million m^3) from tropical forests (Canby et al. 2008). Most of this wood is used for manufacturing furniture that is exported to developed countries. Until 2008, Cameroon, Equatorial Guinea, Gabon and the Republic of Congo accounted for 14 % of Chinese imports of raw timber (Naidu et al. 2008), with significantly less originating from Madagascar.

Chinese customs regulations utilise various classification codes for different forms or types of timber: 44039930 (logs), 94035010 (bedroom furniture) and 94036010 (other furniture). Rosewood trimmed into beams is declared under a different code, but is often mixed in with the other types of timber. For example, under the code for logs imported from Madagascar, Chinese customs lists 4,000 tonnes per year during 2000-2002, 3,000 tonnes in 2004, 4,000 tonnes in 2005, 8,000 tonnes in 2006, no imports in 2007, and 1,000 tonnes in 2008 (James Hewitt In litt.), far less than the amounts known to be exported from Madagascar.

FOREST REGULATION. Many observers have already described the disjointed development of forest regulation in Madagascar (see Ballet and Rahaga 2009, GW and EIA 2009). Even the exporters complain that constantly changing regulations constitute a series of red and green lights. Figure 2 provides a graphic representation of regulation from 1974 to 2009.

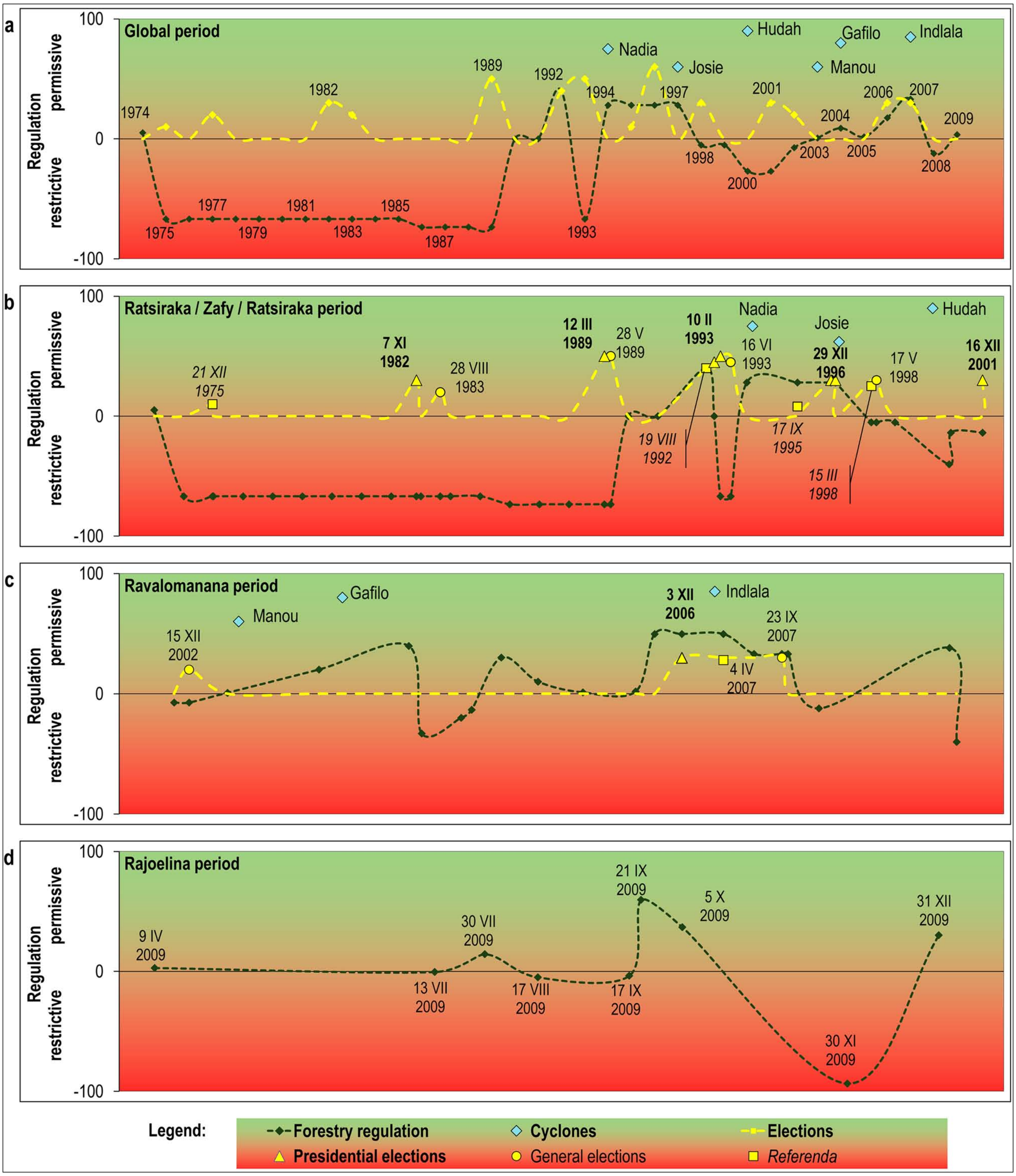

FIGURE 2. Progression of forestry regulation and political events from 1974 to 2009 (a), during Ratsiraka (1974-1993 & 1996-2002) and Zafy periods (1993-1996) (b), during Ravalomanana period (c) and during Rajoelina period (d), with major cyclones shown from 1994 onwards. (Forestry regulation have been calculated by applying indices to strength of legal texts – from 8 = Ordinance to 1 = communiqué; applicability, clarity and functional extent of these legal texts – from 4 = remarkable to 1 = weak; wood targeted – rosewood and ebony =5, palissandre = 1; precious wood harvesting – forbidden = -5, fixed quota = 1, allowed = 5; transportation of precious wood – forbidden = -10, fixed quota = 1, allowed = 10; exportation of precious wood – forbidden = -20, fixed quota = 15, limited to a single type = 10, allowed = 20; taxes – generated = -1, increased = -2; these indices have been standardized between 100 – anything allowed in the forest, and -100 – everything is forbidden in the forest. Cyclones have been shown on the graphics, graded by intensity – Very Intense Tropical, Intense Tropical and Tropical (Service de la Météorologie 2000, World Meteorological Organization 2008). Elections have been differentiated and graded – presidential, general or referendum (African Elections Database 2010).

DISCUSSION

Fraud has taken place along every step in the rosewood trade. Below we first discuss how the traders circumvent government taxation. We then analyze possible forces behind the trade, and conclude with commentary on the socio-economic impact and ecological consequences of the illegal rosewood trade.

REDUCING OR AVOIDING TAXATION. Origin of wood: Cyclones regularly strike Madagascar, and these natural disasters can impact the economy of affected areas. The Government has on several occasions honoured requests from timber traders to recover trees felled by cyclones for export (e.g., Interministerial Order No. 11832 / 2000 following Cyclone Hudah in April 2002). However, field investigations have shown that the majority of trees exported following the passage of a cyclone had not been uprooted by this hurricane but rather were intentionally felled (Stasse 2002, GW and EIA 2009). The United Nations (Joint UNEP / OCHA Environmental Team 2007, cited by GW and EIA 2009) and Birkinshaw and Randrianjanahary (2007) showed that hurricanes have had little effect on trees at Masoala, especially on large, long-lived individuals that are resilient and have survived many severe cyclones. A concrete example of how false information in this regard has been used involves the company Betsiaroana Jean Galbert, who sourced a large amount of rosewood in a concession near Ambohitralalana, Masoala, under license number 842 / MEF / SG / DGEF / DIREF.201 / C.04/02/03 dated 8 August 2000, which expired on 14 August 2003. The technical minutes included in the final post-logging report (No 12 / MINENVEF / CIREEF. 202 / Col dated 26 May 2006) state "(…) after successive hurricanes tearing into the concession, we noted that the following trees have been uprooted: 28 hazinina, (…), 243 Rosewood, 23 bois d ébène (ebony), 39 Nanto [for a total of 420 trees]". According to these numbers, the company claims that cyclones apparently felled mostly rosewood trees but these figures seem totally unrealistic as Dalbergia are certainly among the most cyclone-resistant trees in Madagascar and their natural population density is far less than the 58 % reported here for uprooted trees.

A decade ago more than 60 % of rosewood was taken from national parks, and operational documentation such as logging permits, transportation manifests, storage records and export documentation does not comply with applicable laws (Stasse 2002). Our current estimate that 64 % of wood exported in 2009 is sourced from Masoala and 36 % from Marojejy clearly shows that a majority of wood is now being illegally extracted from Masoala.

Weight issue: Stasse (2002: 8) indicated "When loggers perform weighing – with or without the exporter present – they report the number of logs and the tonnage, accounting for the whole lot. At the port during loading, customs check the number of logs, but not the tonnage declared. The number of tonnes is often undervalued to reduce accrued liabilities, the latter being applied to the tonnage shipped." The port of Vohemar does not have a weighbridge capable of weighing single logs or a container. Customs officials therefore rely on exporter declarations to calculate the weight of a container, which is obtained by summing up the weight of logs reported by the exporters using scales on their own premises. Interestingly, all cargo manifests from Vohemar list logs with the exactly same weight, 200 kg per log. Basing our calculations on a maximum weight of 20 tonnes per container (Table 1), and taking into account the tax increase from $ US 0.05 to $ US 0.25 / kg effective from 21 September 2009, irregularities on the collection of fees are estimated to total as much as $ US 186,000. It is possible that our calculations based on the size of the logs are not fully accurate if the weights declared on the cargo manifests are also false (and therefore undervalued), in which case tax evasion is taking place rather than 'forest fraud'.

Another error has been found systematically in all documentation stating the amount to be charged for export. These forms list an estimate of volume, to which the taxes will be applied, taken from the declared weight on customs forms. Remarkably, these errors, which average $ US 15 per tonne for rosewood, are always in favour of the exporter. The total amount of fraud during 2009 for the known amounts exported can therefore be estimated at about $ US 550,000 (Table 2).

Smuggling: Stasse (2002) estimated that 40 % of the volume exported at that time was smuggled out of Madagascar. In 2009, apart from the 12 containers seized on the Lea in October, the only evidence that we have found of smuggling is as follows: A reference to the shipment of 15 containers without documents in March 2009 from Vohemar (Andriatahina and Rakotondrabe 2009), and a survey by Missouri Botanical Garden (2009) reporting that between 03 February 2009 and 28 March 2009, 469 containers left the country without being reported (and therefore were not included in the total exports listed in Table 2). As we are not in a position to substantiate these figures due to the secretive nature of smuggling, the numbers in Table 2 must be regarded as the only reliable data currently available, providing a conservative estimate.

Repatriation of foreign currencies: Export of rosewood from Madagascar can only be carried out with permission from the Government. The official FOB price, set by the Government at € 2,000 / m^3, is used to calculate the exportation fee (Table 1). The repatriation of foreign currencies imposed by the Government applies to the total amount of the invoice. The FOB prices we found on invoices from exporters in our possession are uniformly close to this amount. We know (see paragraph on settings) that while the actual price received for rosewood is usually around $ US 6 per kilogram (i.e., $ US 6,120 / m^3, Table 1), it can sometimes reach $ US 11 / kg ($ US 11,220 / m^3). The lower price systematically indicated on invoices is thus used to reduce the amount of foreign currency that must be repatriated. Indeed, the bank stamps the invoice for each shipment issued the clearance and therefore must ensure that the total amount indicated in hard currency is returned to its accounts at the end of the export operation. The more an invoice is undervalued, the lower the amount of currency that must be repatriated to Madagascar and then sold to the Central Bank (90 % of the total). Even in the unlikely event that the average price received did not exceed $ US 6 / kg, the total amount of foreign currency generated by rosewood sales in 2009 exceeded the amount required for repatriation by least $ US 52 million. By understating the weight reported for the calculation of export duties, the total amount on the invoice is reduced and consequently the amount to be repatriated is also reduced. Fraud thus adds up.

Fraud on fines: Interministerial order No. 38244 / 209 was signed on 21 September 2009 (Figure 1) to establish a compulsory payment prior to export of $ US 36,000 per contested container held in the port of Vohemar. This requirement could be regarded as a fine for the export of precious timber. This fine is then transferred to a reforestation fund that, however, has no legal basis. The enactment of this order points to a possible diversion of public funds at the highest levels of the State (GTZ 2009 In litt.).

Under this new system, exporters must pay $ US 36,000 per container, precluding the possibility of fraud based on weight or price. However, the order opens a new loophole since it does not specify the capacity of a container, which differs by at least 12.6 tonnes between Vohemar and Toamasina

(Table 1). This may partly explain why large quantities of wood have been transported by boat from Antalaha to Toamasina, where export is more profitable because the port is able to accommodate heavier containers. An exporter from Antalaha went so far as to sell his 'rights' to export 25 containers, as conferred by the order of 21 September, giving the exporter in Toamasina the ability to ship an additional 1,131.5 tonnes of wood. Moreover, the Toamasina-based exporter in question is reported to pay just $ US 5,000 per container rather than the officially required $ US 36,000 (Anonymous 2009). In another example of fraud, two exporters each shipped 43 containers on the Lea on 4 October 2009, well after the new fiscal measures took effect on 21 September 2009, but their export fees were dated from April at the previous, lower rate, a difference of $ US 1.75 million. The case was tried in a Toamasina court on 11 November 2009 but we are not aware of the details of the decision.

INTERNAL AND EXTERNAL FORCES. The MEF and MNP were overwhelmed by the events described in the Introduction. In response, a new entity was established by the Ministry in September 2009 to overcome these problems, the Task Force. In order to appreciate the role of this Task Force, it is first necessary to review the history of forest legislation in Madagascar.

The development of forest legislation and regulation in Madagascar: Figure 2 shows major trends in the development of forest regulation and confirms the impression of a succession of 'green lights and red lights', which can best be understood in relation to the terms of each of the country's presidents.

The period from 1974 to 1989 (Figure 2b) shows high stability in forest legislation and its application. Forests were closed to loggers and there was little or no felling of trees. During this period of revolutionary dictatorship, rosewood export was low and irregular. The Soviets created a few isolated airfields, such as at Doany near Andapa, and transported a limited number of logs by air. Two interesting coincidences can be noted: In November 1992 the relaxation of legislation regulating the export of precious timber immediately preceded presidential elections held on 25 November and general elections the following June; the easing of regulatory legislation again on 30 October 2000, prohibiting logging in the forests except on the outskirts of Antalaha, where the cyclone Hudah struck in April 2000.

Figure 2c corresponds to the Ravalomanana presidency. During this period forests were opened to exploitation on several occasions: In September 2004 after Cyclone Gafilo the preceding March; on 14 September 2006, preceding the presidential elections held on 03 December of that year; and just prior to a referendum held on April 2007. The destructive effect of the interministerial decree issued on 28 January 2009 (authorizing export under so-called 'exceptional' circumstances for thirteen registered exporters) is also evident in Figure 2c. This situation was not improved by the 18 February note prohibiting the transportation and export of ebony and rosewood until an inventory of the total number of logs was completed, as political turmoil was reaching a peak.

Figure 2d, which corresponds to be period during which Rajoelina came to power, clearly shows a 'sawtooth effect' in the impact of regulations. The decision taken on 30 July 2009 authorizing the export of 25 containers of rosewood for each of the 13 operators recognised by Decree 003-2009 against payment of $ US 36,000 per container, followed by the decree of 21 September 2009 confirming permission to export of 25 containers of ebony and rosewood for each of the same traders, again with the payment of $ US 36,000 per container, was abruptly halted by Prime Minister Eugène Régis Mangalaza on 30 November 2009 in a new order prohibiting the sourcing, transport and trade of precious timber.

His successor, Prime Minister Albert Camille Vital, swiftly changed the regulations to allow for logging once again. On 31 December 2009, he issued a note with the same terms as the 21 September decree, but this time there was no deadline. According to our calculations, exports under this Order that have been reported to the State are worth $ US 13.65 million. In addition, there are still 200 containers awaiting shipping from Vohemar, but shipping companies have been reluctant to transport wood from Madagascar following international pressure and condemnation of the illegal logging. Taxes on the wood held up in Vohemar potentially come to $ US 9.3 million, bringing the total to almost $ US 23 million. However, the Deputy Prime Minister, Madame Cécile Manorohanta, declared on 18 December 2009 that the elections announced by the President of Madagascar s transition government and scheduled for 20 March 2010 would cost nearly $ US 15 million (Maka 2009).

It is obvious that on at least three occasions (November 1992, 14 September 2006, and 31 December 2009) restrictions on the trade of rosewood were relaxed just prior to important elections, when funds would be needed and it would be advantageous not to offend voters in the regions where wood is exploited. This predictable, regular pattern strongly suggests that the sale of rosewood is being used to finance Madagascar's 'democracy'. It would be interesting to investigate the reasons behind the closing of forests to logging following elections. Such an investigation would need to include an analysis of the links between forest protection and the allocation of donor support for conservation projects.

The Madagascar judiciary: In the context of Madagascar's constantly changing and frequently contradictory legislative and regulatory environment, the judiciary system is at great pains to apply the law. The hierarchy (slightly simplified) of official documents in Madagascar is as follows: Constitution, law, ordinance, decree, inter-ministerial order, order, note or decision, memorandum, communiqué. Yet the widely accepted principle that lower level documents can not contradict higher level orders is frequently violated in Madagascar. Two examples:

- Interministerial Order No. 003 / 2009 of 28 January 2009 [Figure 1] stipulates in Article 6: "The liquidation of the stocks (…), shall be completed no later than 30 April 2009. After this period, no exemption will be granted (…)", yet Decision No. 338 / 09 / MEF / MI of 30 July 2009 states the opposite: "An export quota of 25 containers of rosewood is assigned to each of the 13 operators in the ministerial decree No. 003-2009 (...)".
- Interministerial Order No. 38244 / 2009 of 21 September 2009 [Figure 1] requires in Article 14 that "(…) the liquidation of stock authorized is to be completed before 30 November 2009 [Figure 1]. After this period, the rosewood from the region of SAVA and that of Analanjirofo may under no circumstances be exported", yet Note No. 218-PM-SP.09 of 31 December 2009 states the opposite: "From the date of signature of this note, operators who have already fulfilled conditions stipu-

lated in the Interministerial Order before 30 November 2009 [Figure 1], in accordance with conditions determined by the Interministerial Order No. 38244 of 21 September 2009 [Figure 1] concerning the export of precious woods (inventories, approval, payment of royalties, taxes and fines ...), can proceed with the preparation and shipment of sending their containers of rosewood."

There are numerous other examples of such contradictions, starting with the Constitution itself, which legislation and regulations have shamelessly violated for years:

- Preamble to the Constitution: "Recognizing the importance of the exceptional wealth and distinctive nature of the fauna, flora and mineral resources with which nature has endowed Madagascar and the importance of preserving it for future generations; (...)"; Article 39: "All persons have an obligation to respect cultural values, public property and the environment. The State and decentralised local authorities guarantee the preservation, protection and valorisation of the environment through appropriate measures."

It should be noted that respect for Madagascar's Constitution is only a formality at present, even though text continues to appear in the introduction to decrees and other official documents. A judge cannot reasonably be expected to condemn someone accused of an offense under the forestry law when the legal basis of the relevant texts is so pliable. Of the 23 exporters mentioned above, 13 have already been brought before a court on accusations of crimes related to forest exploitation, yet only two were convicted while the others were released, apparently due to lack of sufficient evidence.

The ruling elite: The weakness of Madagascar's central power and its poor governance have been highlighted by many authors. Roubaud (2001: 12 and 15) writes: "The disappointment of the public concerning the benefits of the transition is primarily motivated by the behaviour of newly-elected officials who see electoral competition as a way to harness public resources (the diversion of funds is one of many examples of this trend)", and "Contrary to accepted belief, the main obstacle to the development of Madagascar does not lie in the excesses of public regulation, but in its chronic poor administration. Malagasy democracy is ill – not the constituents, but the state and its elites".

Attention was drawn to the forestry sector by Mercier (2006), who described the application of forestry policy and regulations as being hampered by institutional weaknesses and serious problems in governance. More generally, an abundance of natural resources promotes corruption in countries where its institutions have a low level of democracy because it encourages leaders to favour sources of guaranteed income (Bhattacharyya and Holder 2009). Angeles and Neanidis (2009) evaluated the critical role of the local elite in effectively eliciting foreign aid in developing countries. There is a greater likelihood of misusing aid if the ruling class has significant economic and social power along with little regard for the lower classes, and if the ratio of European settlers to the indigenous population was high during the colonial period (Angeles and Neanidis 2009). Madagascar clearly suffers from some severe handicaps.

The GW and EIA (2009) report spells out examples of poor governance and corruption. According to a report by the Task Force (Rasoloson Fanomezana 2008 cited in GW and EIA 2009), Minister Bernard Koto personally intervened on the part of the companies Bezokiny Christian Claude, Ste Thunam Roger et Cie, and Ets Ranjanoro, which led to uncomfortable situations for certain MEF officials. According to MEF's Director of Compliance and Integrity Improvement (DCAI), an officer of the Water and Forest Department was involved with each violation uncovered. Indeed, the temptation is great for a poorly-paid civil servant to benefit personally from his / her position's power to authorize access to forest natural resources, either for firewood or timber (Brinkerhoff 1996). Corruption runs through all government departments involved in rosewood: MEF, the Gendarmerie and Police, the Ministry of Justice, transporters, village chiefs, and mayors of urban centres. This is echoed in a 26 June 2007 World Bank report, which indicates that weak institutional capacity and poor governance diminished the commitment of the Government of Madagascar during the first half of the Environmental Program II (1998-2002). Logging permits were allocated, taking advantage of the fact that the boundaries of protected forests were as yet not geo-referenced nor delimited on the ground.

The activities of the MEF in January 2008 are worth careful scrutiny: Three notes were signed on the same day, 10 January 2008 (01-08 / MEEFT / SG / DGEEF, 02-08 / MEEFT / SG / DGEEF / DRVN / SADG, and 03-08 / MEEFT / SG /DGEEF), cancelling all logging permits and authorizations for timber export. A few days later, on 29 January 2008, the same minister signed two additional notes, one of which set new requirements for obtaining export approval (note No. 086 / 08 / MEEFT / SG / DGEEF / DVRN) and another internal note (No. 005 / 08 - MEEFT / Mi) stating that export licenses were still suspended. Seen from the perspective of operators, it appeared that the Minister Harison Randriarimanana was encouraging loggers to perpetrate acts of corruption to protect their investments, as their products were now subject to confiscation in Antalaha and thus in jeopardy since these ministerial notes were issued (Anonymous 2008b).

The proliferation and inconsistency of regulations in this arena during more than a decade effectively paralyzed justice and encouraged impunity on the part of unscrupulous exporters. We believe there is in fact an organized movement (collective, predetermined behaviour over several years) whose purpose is to stimulate and sustain the activities of the ruling elite. The response of exporters to the proliferation of memos in January 2008 seems to indicate that their preferred option was to try to reverse any decision not in their favour by means of corrupting the authorities. This was done by attempting to convince policy-makers based in the capital that their decisions were inappropriate and counter-productive, and that they encourage foreign competition. The unstable nature of the forestry regulations is the result of decisions made at the highest governmental levels, giving those holding power at the central and regional levels in each department the opportunity to negotiate and cut a deal. This applies, for example, to State responses to natural disasters, preparations for elections, improving the balance of payments, the prestige of personal influence and efforts to increase votes for a chosen candidate.

China and U.S. Lacey Act: The stringent measures implemented by the Chinese government to stop environmental disasters in its own country have had serious repercussions on the rest of the world. Since China banned logging in its own forests in 1998, imports of timber have increased six-fold, making it second only to Japan in purchases from countries with tropical rainforests. By actively protecting their own forests and thereby "exporting deforestation" (Liu and Diamond 2005), China and Japan are wreaking havoc in places such as Malaysia, Papua New Guinea, Australia, and now Madagascar.

Records of Chinese imports show that the main suppliers of rosewood in 2008 were Myanmar (41,000 tonnes) and Mozambique (27,000 tonnes) (James Hewitt In litt.). However, our sources are unsure that the rosewood reportedly exported by Mozambique in fact came from that country: Madagascar, located just across the narrow Mozambique Channel, exported around 36,000 tonnes in 2009. It is both interesting and important to note that Chinese customs records indicate only 1,000 tonnes of logs as originating from Madagascar in 2008, while the amount of rosewood exported from Madagascar that year reached almost 14,000 tonnes. China has always been the major buyer of Malagasy rosewood (e.g., 98 % about a decade ago, Stasse 2002) and in 2009 almost 100 % of exports were shipped there. As long as countries such as China use customs codes that do not allow transparency of imports and origins, it will remain almost impossible to track the rosewood trade accurately. In this regard, the United States has been exemplary in its implementation of the Lacey Act, which prohibits the import of illegally sourced timber. The aim of this act is to shift part of the responsibility to the US as an importing country rather than leaving it entirely in the hands of the exporting / source country.

The donors: Madagascar's unique and threatened biodiversity has, for more than two decades, made it a high priority for the international conservation and development community. Donors congregated in Madagascar in 1991 for a Multi-Donor Secretariat (MDS), representing the International Non-Governmental Organizations (INGOs) – Worldwide Fund for Nature (WWF), Conservation International (CI), Wildlife Conservation Society (WCS) – and Agencies for Development of the countries concerned (France, Germany, Japan, Norway, Switzerland and USA), plus the United Nations and the World Bank. Over $ US 320 million has been invested by members of this community. Yet the silence of the donors and INGOs during 2009, when efforts made over many decades to protect natural assets quickly collapsed, is puzzling. Where are the results of the massive financial aid they channelled into the country? When President Ravalomanana stepped down on 17 March 2009, the international community responded by immediately suspending all financial assistance, except some humanitarian aid. Lenders, donors and the INGOs suddenly found themselves deprived of any leverage, which proves that their influence was only financially driven – no more money means no more influence.

The Malagasy State depends on international assistance, and even more so for the funding of the National Environmental Action Plan, which relies on foreign funding for more than 80 % (Rabesahala Horning 2008). The donor institutions and INGOs left the door wide open for the logging syndicate to lobby those in power and to do so successfully. Given the near-complete silence of the INGOs, there is growing international sentiment that the donors might not appreciate the lack of tangible results for their support and there is also concern that the INGOs actually have had a corrupt interest in minimizing the gravity of the forestry crisis in 2009, lest their funds dry up. According to Rabesahala Horning (2008), the local elite treat aid as an "annuity" – a "mass of money" that is automatically due to the country because of the "uniqueness of Madagascar's biodiversity on a global level".

IMPACTS. Impact on parks: For several months during 2009, thousands of people were involved in logging rosewood and ebony in the protected areas of the SAVA and Analanjirofo regions. The logged portions of the Masoala Park amdount to approximately 4,000 he ox industry annually brings nearly a half-billion US dollars to tens of thousands of people involved in all aspects of the industry (hotel and restaurant staff, guides, drivers, taxi operators, boat skippers, artisans and more). By contrast, the illegal high-end timber industry has resulted in a one-time windfall of an estimated $ US 220 million (Table 2) for just twenty-three individuals and a smattering of minor payments to a limited number of other players involved.

As the eco-tourism industry continues to decline in tandem with the degradation of the forests and of security, the very image of Madagascar itself has been severely tarnished. Those with some common sense have just cause for alarm: More than just logs of rare timber are leaving the country – jobs, livelihoods and reputations are at stake. On several occasions over the past decade, the government has banned the export of unprocessed precious wood (i.e., in the form of logs). According to Global Witness (GW and EIA 2009), a large rosewood cabinet sells in China for between $ US 18,700 and $ US 25,000, and a Chinese importer would pay $ US 750 to 1,000 for the raw material bought from exporters in Madagascar. If a Chinese consumer spends $ US 25,000 on a cabinet, then his compatriots involved in processing, distribution and importing retain $ US 24,000, compared with the $ US 1,000 that accrues to the Malagasy sellers (Table 1). The Chinese interests involved in the industry are thus earning nearly 25 times more than their Malagasy suppliers, and 357 times more than the villagers working in Malagasy forests, who earn around $ US 67 (Table 1).

Vast sums of money are required to remove large amounts of rosewood and ebony from remote forests and transport them to stored sites until the administrative situation is favourable (which can take years), and then exporting the wood involves paying heavy taxes (Table 1). Most exporters simply do not have the necessary funds themselves, so they resort to ingenious ways to circumvent making payments or to reduce the amounts they have to pay. For example, some exporters have diverted funds provided by the BOA that should have benefitted the vanilla industry, and it is thus hardly surprising that the price of Malagasy vanilla was particularly low in 2009. This is not just a consequence of the law of supply and demand nor the minimum prices set by Ministers ($ US 27 per kilogram in 2009), but rather a lack of motivation on the part of farmers to produce good quality vanilla in sufficient quantities. If the exporters of rosewood – most of whom also export vanilla – tell producers that they will buy little or no vanilla in a particular year, thereby making farmers aware of an impending plunge in the price of vanilla, the farmers will naturally go into the forests to cut rosewood, because they know there will be firm orders and guaranteed prices that are far more attractive. This is precisely how the timber exporters corralled their workforce: Through economic coercion they deliberately forced people who would ordinarily have been involved in the vanilla industry into the illicit rosewood industry.

Another noticeable consequence of illegal rosewood exploitation has been the closure of schools in remote villages, particularly around Marojejy National Park. This results directly from the economic ills suffered by the local communities, principally because of the low (fixed) price of vanilla, which has made it impossible for villagers to afford school fees or pay teachers' salaries. So the schools are closed, at least temporarily, and the children are sent to work the rice fields because they must eat every day. A new generation of woodcutters thus grows up lacking education, ignorant of the world around them.

CONCLUSION

For more than ten years, Madagascar's rosewood industry has followed what has now become a regular cycle:

1. Under the influence of environmental donors (who must demonstrate visible results during the lifetime of their projects), the government enacts sound forestry legislation and takes restrictive regulatory measures, but it does this without having the capacity, human OR moral, to apply them;
2. Since export of precious timber is illegal, rosewood loggers accumulate stocks, either discretely or overtly, as is currently the case in Vohemar and Antalaha, where there are numerous rosewood caches. The law is publicly disregarded, officials charged with its application are disoriented, and the authority of the State is weakened;
3. Taking advantage of an external event such as a cyclone, an election, or a difficult political transition, lobbying by the logging syndicate is heard and acted upon by the governing class, which then issues a series of orders authorising the exceptional one-time export of the stockpiled wood (examples: 2000, 2004, 2005, 2007, 2009), apparently without the possibility of later exemption (although we note that the number of examples clearly illustrates many exemptions);
4. Logging companies export massively, attempting, often with success, to involve members of the governing class in their business;
5. Once the donors raise their voices, there is a (temporary) return to Phase 1.

It is important to note that illegal exploitation continues throughout the entire cycle, as the government only really controls the export process (i.e., from the loading of containers on board a ship in port to its departure). Timber exporters accumulate stocks while waiting for a favourable phase in the cycle, a process that will almost surely continue until the resource is totally depleted. For some, the forest is a refuge of unique biodiversity, while for others it is simply an adjustable budgetary variable. And for others still, it is a source of personal enrichment.

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We express our warm gratitude to all those who provided information on export of the varied aspects of the rosewood trade. They include businessmen, politicians, officials of MEF, customs and port officials, judges, journalists, agents of Madagascar National Parks, tourist guides, artists, bankers, radio hosts, hotel employees, truck drivers, lumberjacks, collectors and exporters. Many have taken great risk to speak with us, some have been threatened with death, another had his house burned, and one had his foot crushed. Without these peoples' courage to speak out, we would not have been able to write a line of this article. The people of Madagascar will never really know how indebted it is to the many anonymous and unsung heroes.

We applaud the Missouri Botanical Garden (St. Louis, USA) who, through personal commitment of its president, Peter Raven, and his collaborators, was the first foreign institution

– and unfortunately the only one – to have demonstrated the courage to publicly denounce the situation in Madagascar at the World Forestry Congress in Buenos Aires in October 2009 and the UN Climate Change Conference in Copenhagen later that year. It has indeed been thanks to the work of this institution that the media began to give exposure to the crisis surrounding Madagascar's rosewood.

Finally, we express our gratitude to the four anonymous reviewers who spent considerable time improving this study.

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Combined biomass inventory in the scope of REDD (Reducing Emissions from Deforestation and Forest Degradation)

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ABSTRACT
This paper presents an approach for combined biomass inventories in the scope of future REDD regimes. The focus is set on a sound and reliable method for measuring and monitoring the current state of carbon stocks and their changes over time. A reliable framework for measuring, reporting and verification is urgently needed to ensure the integrity and credibility of REDD efforts in general and REDD in the post-2012 agreement which is assumed to be approved at COP 16 in Mexico in December 2010. The proposed approach was developed and successfully implemented in Madagascar within a multi-institutional REDD project, i.e., REDD-FORECA. It combines a multi-temporal remote sensing approach incorporating satellite sensors from medium to very high resolution with a terrestrial cluster sampling design, which proved to be operational for the whole spectrum from highly fragmented to pristine forest areas. This combination was implemented by a multi-phase sampling approach. The inventory is designed for the prerequisites of a continuous forest inventory to facilitate the quantification of possible CO_2 reductions over time. The first field-assessments were accomplished in 2007 and 2008, and resulted in estimates of aboveground biomass on single tree level. Statistical upscaling procedures were utilised to aggregate these estimates on several levels. The results of the introduced methodology are presented and discussed.

RÉSUMÉ
Cet article présente une approche concernant les inventaires de biomasse combinés dans le cadre des futurs régimes REDD. Elle porte sur une méthode fiable et avérée pour mesurer et contrôler l'état actuel des stocks de carbone et leur évolution dans le temps. Un système fiable de mesure, de suivi et de vérification est nécessaire pour garantir l'intégrité et la crédibilité des efforts investis dans REDD en général d'une part et du mécanisme REDD dans les accords post-2012 devant être approuvé à Mexico en décembre 2010 lors de la COP 16, d'autre part.

Dans la mesure où REDD doit pouvoir être appliqué par l'ensemble des pays en voie de développement, l'accent a été mis en particulier sur la possibilité de transférer la méthode en tenant compte des particularités nationales et régionales des divers pays concernés. L'approche proposée a été développée et mise en œuvre à Madagascar avec succès dans le cadre d'un projet REDD (REDD-FORECA) impliquant plusieurs institutions. Elle associe une approche basée sur la télédétection multi-temporelle, intégrant des capteurs de moyenne à très haute résolution avec un plan d'échantillonnage terrestre en 'cluster'. Elle s'est avérée opérationnelle sur l'intégralité du spectre des surfaces forestières, depuis les parcelles extrêmement fragmentées aux forêts intactes. Cette possibilité d'adapter la méthode à une large variété d'états de la forêt a été testée et vérifiée. Cet article met de plus en lumière la possibilité de détecter et de quantifier le déboisement et la dégradation des forêts. La méthode présentée permet d'estimer de manière fiable la biomasse forestière et son évolution dans le temps, à un coût total et avec des erreurs d'échantillonnage raisonnables. Cela a été possible grâce à une démarche d'échantillonnage à plusieurs phases en combinant des phases de télédétection avec une phase terrestre d'inventaire. Un contrôle rigoureux des erreurs d'échantillonnage lors de chacune de ces phases est essentiel pour générer des bénéfices dans un mécanisme REDD. L'inventaire est conçu de façon à remplir les pré-requis de tout inventaire forestier continu afin de faciliter la quantification des éventuelles réductions de CO_2. Les premières mesures sur le terrain qui se sont déroulés en 2007 et en 2008 ont permis d'estimer la biomasse au-dessus du niveau du sol. Pour dériver ces estimations à des niveaux d'agrégation plus élevés, des procédures ascendantes (upscaling) ont été utilisées. Les résultats de la méthodologie employée sont présentés et discutés.

KEYWORDS: Combined inventory, remote sensing, biomass, Reducing Emissions from Deforestation and Forest Degradation (REDD), Madagascar.

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MOTS CLEFS : inventaire combine, télédétection, biomasse, réduction des émissions du déboisement et la dégradation forestière (REDD), Madagascar.

INTRODUCTION

According to estimates of the Intergovernmental Panel on Climate Change (IPCC) an annual total of 1.6 billion tons of carbon are released worldwide by land-use change activities, of which a major part results from deforestation and forest degradation (Denman et al. 2007). Following the Stern Report (Stern 2007) carbon emissions from land-use change accumulate to nearly one-fifth of today's total annual emissions, most of which can be traced back to tropical deforestation. The avoidance of deforestation and forest degradation is not accepted so far as an eligible action in the current commitment period of the Kyoto Protocol, i.e., 2008-2012. In 2005 the Eleventh Session of the Conference of Parties (COP 11) to the United Nations Framework Convention on Climate Change (UNFCCC) initiated a process for considering a policy for reduced emissions from deforestation and forest degradation (REDD).

REDUCING EMISSIONS FROM DEFORESTATION AND FOREST DEGRADATION (REDD). Some economical incentives for reducing the emissions of greenhouse gases (GHG) exist in the Kyoto Protocol. In the articles 3.3 and 3.4 the benefit of forests as carbon sinks are considered (UNFCCC 1998) and in the Clean Development Mechanism measures for afforestation and reforestation can be accounted for generation of credits. These financial measures reward the function of forests as carbon sinks or carbon sequestration by local to regional re- or afforestation activities. In contrast, REDD focuses mainly on the maintenance of forest carbon stocks through compensation of potential direct or indirect economic benefits of deforestation and forest degradation on a national level. As developing countries, sheltering the major part of the existing tropical forests, have shown high rates of deforestation in the recent past, the process REDD is expected to become an important element for reduction of GHG emissions into the atmosphere. However, effective incentives leading to a reduction of deforestation and forest degradation are still a topic of ongoing discussions. To ensure the integrity and credibility of REDD efforts in general and REDD in the post-2012 agreement a reliable framework for measuring, reporting and verification is urgently needed (UNFCCC 2007). As a consequence thereof, the parties at COP 15 in Copenhagen acknowledged a decision on the methodological guidance for activities relating to REDD and therein request the establishment of robust and transparent national forest monitoring systems (UNFCCC 2009). It is assumed that a legally binding agreement on REDD will be integrated in a post-2012 agreement at COP 16 in Mexico in December 2010. Nevertheless, each country choosing REDD as an option for mitigating GHG emissions needs to set up its own national strategy and monitoring system that has to adhere UNFCCC standards. Implementing a viable REDD regime involves several steps:

(1) Initiating a system for the assessment of forest carbon stocks and their change over time;
(2) quantifying the amount of reduced CO_2 emissions, which qualifies for accounting;
(3) identifying and ranking of the relevant causes for human impact on forests in order to derive effective measures to combat the degradation of forests;
(4) definition of a reference level (i.e., baseline), against which the changes of carbon stocks in forests are set off; and
(5) implementing a scheme for the transfer of benefits to local actors.

PILOT PROJECT REDD-FORECA. REDD-FORECA is a multi-partnership pilot project in Madagascar that was set up to develop methodological approaches to monitor accountable reductions of GHG emissions due to deforestation and forest degradation activities, to develop possible incentives to realise these reductions, and to integrate the results into the political decision-making process of Madagascar. In REDD-FORECA the German von Thünen-Institute (vTI) and the Malagasy scientific partner ESSA Forêts collaborate with the 'Swiss Foundation for Development and International Cooperation' (Intercooperation) and the 'Gesellschaft für Technische Zusammenarbeit' (GTZ), as well as with various cooperation partners in Madagascar, i.e., inter alia local and national forest authorities. The focal point of the pilot project was set on natural forests as plantations or managed forests are not likely to be a part of REDD.

CARBON FLUXES. As REDD focuses on the maintenance of already existing carbon stocks in natural forests five major carbon pools are to be considered: (1) Aboveground biomass, (2) below-ground biomass, (3) dead wood, (4) litter, and (5) soil organic matter (IPCC 2006). By increasing at least one pool, while maintaining the other pools forests become a carbon sink. However, respecting the complexity of natural systems, all these five carbon pools are highly interdependent and in a steady state of flux (Longdoz et al. 2004, Nabuurs 2004).

Currently there is a contradictory debate on the amount of carbon transferred by the decay of living biomass, i.e., pools 1 and 2, to the atmosphere and to soils, i.e., pool 5. Despite growing interest on this topic, there are no long-term studies in tropical areas on soil carbon fluxes that could allow reliable inferences to the scope of REDD. Thus, the following brief overview on different positions in this debate concentrates on studies from temperate regions. While some publications suggest an increase of organic soil components and thus an increase of carbon sequestered by soils (Freibauer et al. 2009), others report no significant changes in soil carbon or even a release of soil carbon to the atmosphere. Schlesinger and Lichter (2001) studied soil carbon in *Pinus taeda* stands and found high transfer rates of organic carbon in the litter layer, i.e., pool 4, but an absence of carbon accumulation in the mineral soil. They conclude that a significant, long-term net carbon sequestration in soils is an unlikely event. Bellamy et al. (2005) analysed data of the National Soil Inventory in England and Wales, which were assessed between 1978 and 2003. They report a mean annual release of 0.6 percent of the existing soil carbon stock, which compensates with high probability the carbon sequestration by soils. In accordance with the IPCC Good Practice Guidance for National Greenhouse Gas Inventories (IPCC 2006) it was assumed that carbon uptake and carbon release by soils is at equilibrium and that it is justifiable to exclude this pool from accounting. Furthermore, we assume that the carbon sequestration by living biomass in natural forests is on the long run in balance with the carbon offset by the decay of dead organic matter. Thus, natural forests are neither a carbon sink nor a carbon source.

For these reasons the presented methodology will focus on the quantification of living aboveground biomass, which can be subsequently transformed into carbon stock. Changes of the carbon stock are induced by either a total loss of biomass due to deforestation and associated land-use changes or by a net-reduction of biomass stock, i.e., forest degradation. Hence the REDD-FORECA project in Madagascar had inter alia the objective to assess changes of forest area and changes of living biomass stock.

A multitude of methods exist to fulfil this objective. This article illustrates both the development of a methodology for the assessment of forest carbon stocks and their changes over time, and the possibilities of quantification of the amount of reduced CO_2 emissions, which qualifies for accounting. Furthermore, the results after the methodology's appliance are presented and discussed.

INTRODUCTION INTO THE METHODOLOGY

To assess changes in forest area and of living biomass on a national scale combined inventories, i.e., the combination of remote sensing (RS) data and in-situ assessments, have been advised by IPCC (IPCC 2006) and proven to be cost efficient and operational on the one hand and to lead to reliable results on the other hand (Bowden et al. 1979, Scott and Köhl 1994, Achard et al. 2002, IPCC 2003). For this purpose the top-down approach is a commonly used and operational methodology on national level. In the following paragraphs the subsequent steps of this multi-phase approach, as illustrated in Figure 1, are outlined.

In a first step a full coverage of the country's area (wall-to-wall map) can be obtained by remote sensing imagery data. The quality of such data depends on its spatial, spectral, radiometric and temporal resolutions. The wide variety of RS sensors and their specific characteristics have been classified by DeFries et al. (2006) for the particular needs of REDD (Table 1).

The information of the wall-to-wall map can be specified by the usage of sensible auxiliary data on e.g., climate, topography or vegetation classes to derive broad regions of the country's area. Within these regions thematic classes, i.e., non-forest and forest areas can be obtained in a second step by further classifying the remote sensing data. The non-forest and forest areas are considered to be homogeneous groups or strata (Remote Sensing Phase 1, in Figure 1). In general the stratification of an area of interest into sub-areas or strata has the objective to form homogenous sub-units. In most situations, stratified probability sampling is likely to yield more precise population estimates (i.e., estimates with smaller standard errors) than non-stratified probability sampling with the same sample size.

To obtain information on the development of a country's forest area the changes over time between the forest and non-forest areas have to be analysed by applying change detection algorithms for archive and present data (time 0, time 1, in Figure 1).

In contrast to a national forest inventory (NFI), a combined inventory in the scope of REDD needs to concentrate mainly on forest areas that show ample changes in their spatial extent. The use of change detection algorithms integrated in multi-tem-

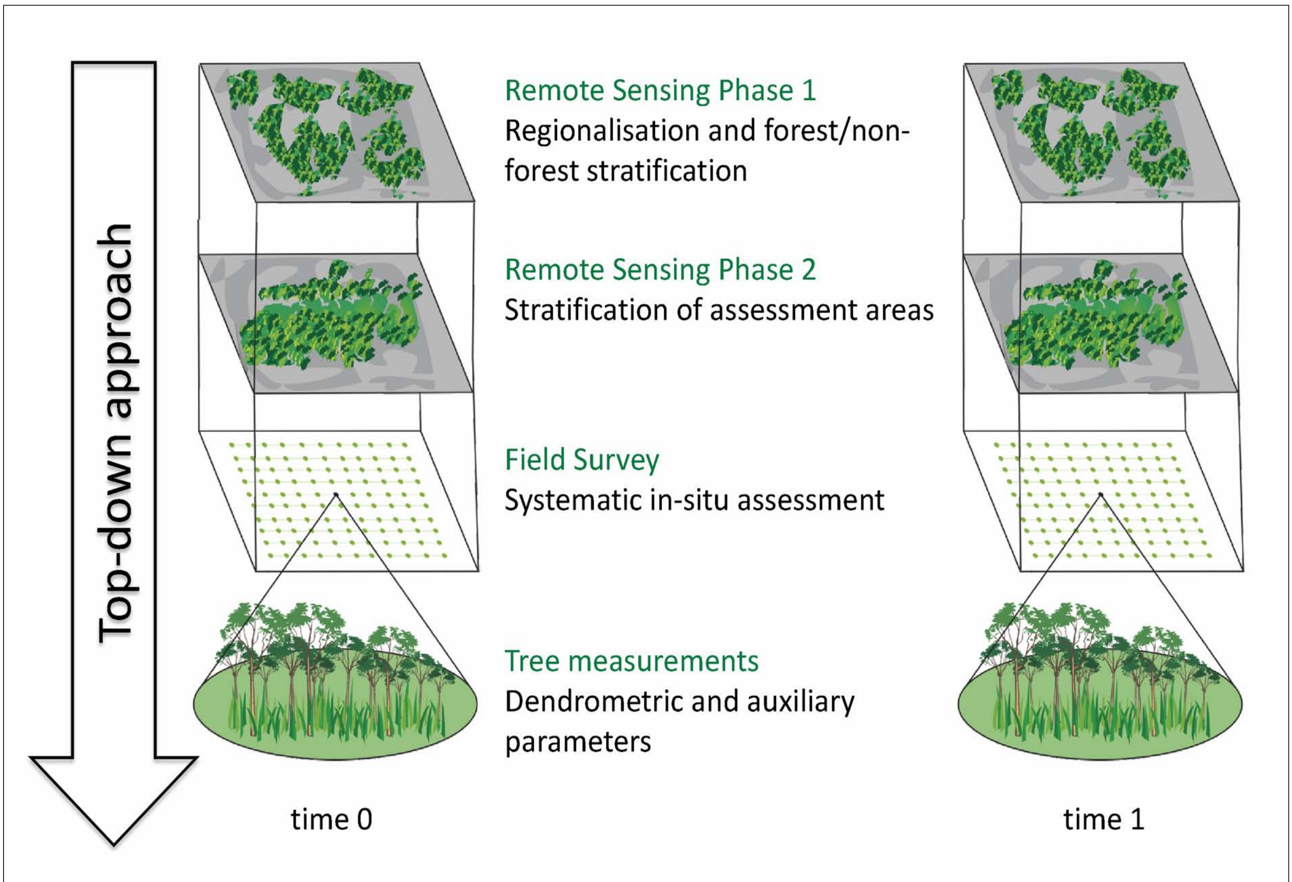

FIGURE 1. Top-down approach for a combined inventory on national scale.

TABLE 1. Utility of optical sensors with different resolutions in deforestation monitoring (after DeFries 2006).

Sensor Resolution	Examples of Current Sensors	Utility for Monitoring	Cost
Very high (< 5 m)	IKONOS, Quickbird	Validation over small areas of results from coarser resolution analysis	Very high
High (10-60 m)	Landsat, SPOT HRV, AWiFsLISS III, CBERS	Primary tool to identify deforestation	Low/medium (historical) to medium high (recent)
Medium (250-1000 m)	MODIS, SPOT Vegetation	Consistent global annual monitoring to identify large clearings (>10-20 ha) and locate "hotspots" for further analysis with high resolution	Low or free
Data from optical sensors have been widely used for deforestation monitoring. Data from Lidar and Radar (Ers 1/2 SAR, JERS-1, ENVISAT-ASAR and ALOS PALSAR) have demonstrated to be useful in project studies, however, so far are not widely used operationally for tropical deforestation monitoring. An exception is the use of SRTM data, which were acquired by an active RADAR sensor.			

poral data can be combined with socio-economic data (e.g., accessibility, number and distribution of settlements), which allows detecting both possible 'hot spots' with high rates of deforestation and forest degradation, and undisturbed areas. Assessment areas, where the in-situ assessments are carried out, can be selected from these hot spots following specified criteria.

In a third step the assessment areas can be further analysed to identify different strata inside the forest area (e.g., closed forest, open forest) through the utilization of high or very high resolution imagery. The combination of different sensors on different scales for this purpose is commonly utilized and proposed by e.g., FAO (2007).

In a next step the design of the in-situ assessment has to be chosen. A multitude of options for the allocation of sample plots (SP) within the strata, like for example, simple random sampling or systematic random sampling, exist and can be found in the specific literature (Loetsch et al. 1973, Synnott 1979, Adlard 1990, IPCC 2006, Köhl et al. 2006). Nevertheless, especially for pilot assessments, where little is known on the characteristics of the forest, a systematic sampling design of the in-situ phase is advised (Saket et al. 2002). Here the sample plots are allocated on a systematic grid in each stratum, thus facilitating the assessment of dendrometric and auxiliary data to obtain information on living aboveground biomass.

To enhance the cost efficiency and feasibility of this approach and taking into account the difficulties of hard to access, remote areas of tropical forests, it is advised to apply cluster sampling. An introduction into the methods and statistical peculiarities of cluster sampling can be found in the literature (Loetsch et al. 1973, Cochran 1977, Köhl et al. 2006, Mandallaz 2008). A measure for the efficiency of cluster sampling is the intra-cluster-correlation coefficient (ICC), which is presented for each of the assessment areas in the results chapter (see Results).

APPLIED METHODOLOGY

For the present pilot project in Madagascar an assessment method for monitoring current state and changes of forest carbon stock has been developed and applied. This method combines the capacities of remote sensing techniques to assess spatial data on forest areas with the potential of sample based field surveys to capture even small changes in forest carbon stock. A detailed illustration of this applied methodology is shown in the Supplementary Material.

To assess natural forest carbon stocks and their changes over time it is indispensable to define 'forest'. From the several existing definitions (UNFCCC 2001, Schoene et al. 2007) the minimum benchmarks defined in the Marrakesh Accords were chosen, in order to realise the inclusion of small forest fragments severely threatened to be finally deforested as well as the dry forests in southern Madagascar. These are (i) a minimum area of 0.05 hectare, (ii) a tree crown cover of more than 10% and, (iii) the potential to present trees that reach at least two meters height in-situ. To the knowledge of the authors Madagascar itself has not yet decided on a definition of forest for the scope of REDD.

Figure 1 shows the subsequent steps of the applied top-down approach. The implementations of these steps in Madagascar are described in the following.

REGIONALISATION OF THE LAND AREA OF MADAGASCAR.

There are a number of factors influencing the amount of aboveground biomass stocks in forests, resulting in a broad range of these in a single country. However, only some factors are feasible for breaking down a country's land area into homogeneous groups, thus dividing the whole range of possible forest aboveground biomass (AB) into specific, consistent compartments. The aim of the regionalisation in this project was to reduce cost and to increase the accuracy of field assessments. Within the 'Good Practice Guidance for Land Use, Land-Use Change and Forestry' (GPG-LULUCF) (IPCC 2003) stratification rules for broad forest categories related to aboveground biomass stocks are presented, which can be applied worldwide. These rules are shown in Table 2 for tropical forests.

In order to assign these IPCC categories to Madagascar the following input data have been used (see Figure 2): (i) Data of the Moderate Resolution Imaging Spectroradiometer (MODIS), (ii) data of the Shuttle Radar Topography Mission (SRTM) and, (iii) information on climate.

A regionalisation of Madagascar was performed using a supervised classification of these data. This common technique uses RS-data with terrestrial reference data in order to assign discrete or continuous classes to areas. Within the classification process, in this case a maximum likelihood classifier was used, statistical parameters were derived from the RS-data and resultant features thereof (Lillesand et al. 2004).

RS-data generally has to be pre-processed before performing analyses, i.e., geometric and radiometric corrections. These processes lower the estimated errors in the results. Additionally, the use of passive sensors demands, especially in the tropics, the masking of clouds and shadows in RS-data, as these areas cannot be further processed.

Time series of MODIS data were applied for the monitoring of forest cover changes by deforestation on large areas and the identification of hot spots. In doing so, the use of expensive, very

TABLE 2. Aboveground biomass stock in tons per hectare per forest formation (adapted from IPCC 2003).

Tropical Forests						
	Wet	Moist with Short Dry Season	Moist with Long Dry Season	Dry	Montane Moist	Montane Dry
	P > 2000	2000 > P > 1000		P < 1000	P > 1000	P < 1000
Africa	310 (131-513)	260 (159-433)	123 (120-130)	72 (16-195)	191	40
Asia & Oceania:						
Continental	275 (123-683)	182 (10-562)	127 (100-155)	60	222 (81-310)	50
Insular	348 (280-520)	290	160	70	362 (330-505)	50
America	347 (118-860)	217 (212-278)	212 (202-406)	78 (45-90)	234 (48-348)	60
Note: Data are given in mean value and as range of possible values (in parentheses)						
P: Annual Precipitation						

high resolution remote sensing data could thus be restricted to small hot spots to get detailed insight in the spatial development of forest cover. While high resolution sensors provide information on forest cover for small areas, the very high cost associated with their application renders their use on extensive areas not feasible. Regarding the needs for the REDD-FORECA project, sensors with different spatial resolutions needed to be integrated in order to provide a manageable and affordable spatial database.

In the recent past the capabilities of the sensor MODIS regarding the classification of forests have been intensively tested and discussed (Kleinn 2002, Bucha and Stibig 2008, Andersson and Richards 2009, FAO 2009). Hansen et al. (2008) used MODIS data to generate a regional forest / non-forest cover map in the Congo Basin. Moat and Smith (2007) produced an atlas of the vegetation of Madagascar based on MODIS data. Despite the fact, that this data source has a spatial resolution of 250 m and thereby does not allow for exact area and area change calculations due to the mixed pixel issue, FAO proposes its use for monitoring in an integrated approach with higher resolution data (FAO 2007). This integration was implemented in the applied top-down approach.

In addition, Shuttle Radar Topography Mission (SRTM) data were used. This active sensor provides data on topographic information. Data from this sensor are available from the U.S. Geological Survey (USGS) free of charge and have been used since 2000 (Toutin and Gray 2000, van Zyl 2001). An adequate source on climatic information for Madagascar is the classification in climate zones by Cornet (1974). Unfortunately, available national forest inventory (NFI) results of the 1990s were only of limited use, as neither complete original data sets could be obtained nor did the available data fulfil the requirements for REDD.

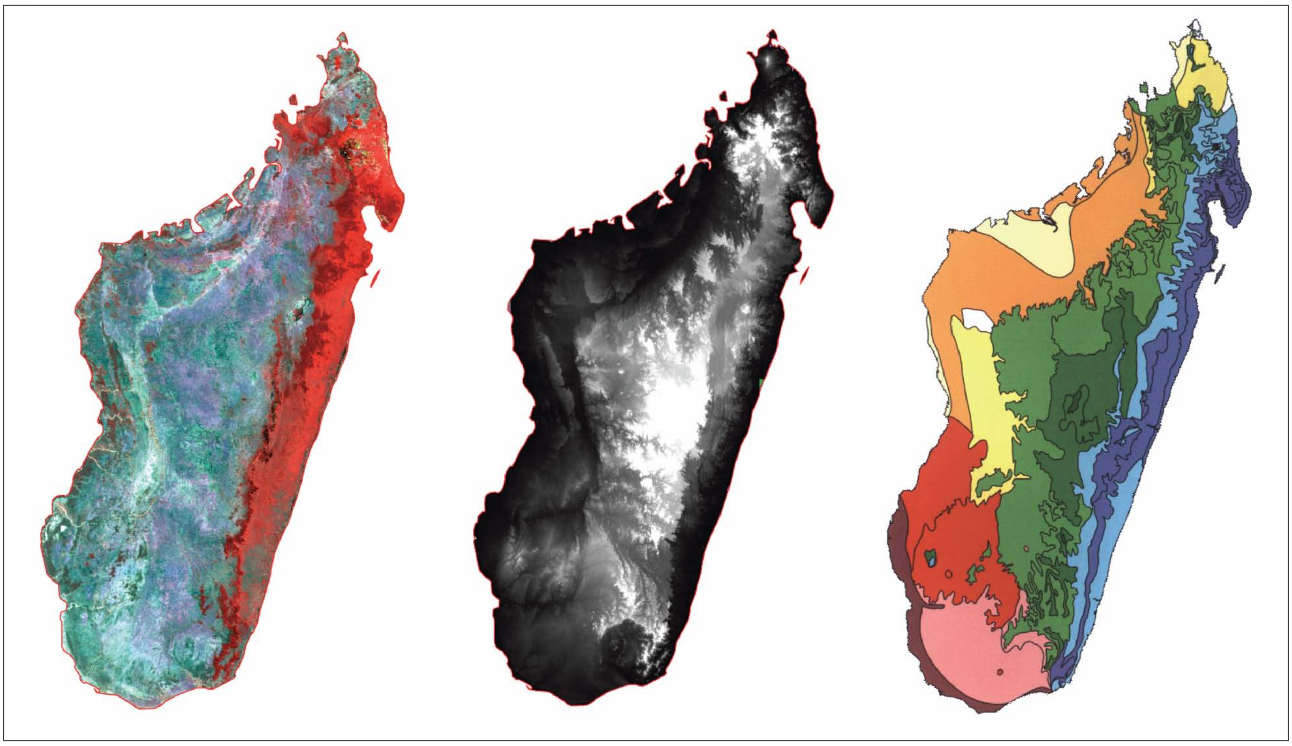

FIGURE 2. Input data for the supervised classification (from left to right): Layer stack of MODIS_13q1 (2-3-1) dated 2007-08-29, SRTM-data (darker spots represent lower areas), climate map based on Cornet (1974).

Furthermore, a criteria list was developed to identify assessment areas. In this list the prerequisites for the selection of an assessment area were defined according to their importance. First, the assessment area has to be representative for the above derived regions. Second, the derived results should be transferable to areas with similar characteristics in other tropical countries. Third, the assessment area has to exhibit different intensities of deforestation and forest degradation. Furthermore, criteria like infrastructure, accessibility and temporal feasibility were included. Considering the above named criteria and due to time restrictions a further aggregation of the categories proposed by IPCC to only three categories was realised and resulted in the following regionalisation of the country and subsequent identification of three assessment areas (see Figure 3 and Table 3).

STRATIFICATION OF ASSESSMENT AREAS. In a next step forest areas within the assessment areas had to be identified. Here, an unsupervised classification algorithm, where RS-data is classified into spectrally similar clusters, was applied. This classification method is performed automatically, and in contrast to the above illustrated supervised classification, no reference data is used for the procedures. As a result, the RS-data is divided into a selected number of categories with similar characteristics of their radiometric information. In order to determine the number of radiometric separable classes for the assessment areas, scatter diagrams were used, where the combination of applied spectral bands of the RS-data was examined.

This classification based on the assessment areas has a high potential for error reduction as the classification results were used for stratification. The aim of this stratification was to identify forest and non-forest areas in the assessment areas. Data of the passive, high resolution SPOT 4 and SPOT 5 sensors were used. Both sensors record four spectral bands, i.e., green, red, near infra-red and short-wavelength infrared light.

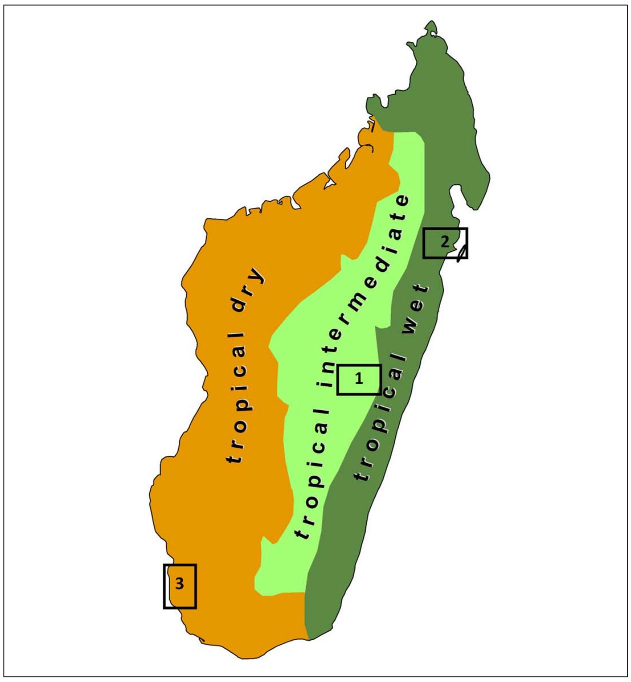

FIGURE 3. Regionalisation of Madagascar's land area based on aggregated IPCC categories; black boxes show the identified assessment areas: No. 1 Tsinjoarivo, No. 2 Manompana and No. 3 Tsimanampetsotsa.

The assessments of both forest area and carbon stock changes over time demands for repeated successive assessments. This was realised by the acquisition of remote sensing imagery from two points in time and a subsequent multi-temporal image analysis. In medium and high resolution imagery changes of the spatial distribution of forest areas were identified, while very high resolution imagery facilitated the identification of advanced stages of forest degradation. Performing a change detection analysis for the archive and the present data permitted statements on the development of these forest areas.

The primarily result was a number of intermediate classes in these forest areas, which in a second step had to be fused into the classes forest and non-forest following the parameters of the chosen forest definition. It was detected that in Madagascar two diverse types of forest fragments exist. Firstly, contiguous or almost contiguous forest areas, i.e., nearly one large forest fragment, could be detected. Secondly, small, more fragmented forest areas were identified. These circumstances gave the reason for the need for a flexible methodology, in order to keep total errors in the inventory low. Keeping errors in a reasonable scale generally requires more expenses for the field assessment. These fragments of forest were subsequently inventoried within the in-situ assessment, which was implemented in order to get sensitive information on forest degradation, i.e., the development of forest carbon stock, and to be able to quantify the loss of biomass due to deforestation activities.

IN-SITU ASSESSMENT. Cluster sampling was applied to facilitate the acquisition of field data in remote and hard to access areas on the one hand and to lower the cost of the field survey on the other hand. In more fragmented forest areas cluster sampling yields the flexibility to be adapted to area specific conditions. Two different cluster layouts for the identified assessment areas (see Figure 4) were applied. In general, different cluster layouts may also be applied for different strata within one assessment area but not within a single stratum. On the sample plots (SPs) of these clusters a multitude of data was assessed during the in-situ assessments from September 2007 to October 2008. These included dendrometric data, such as DBH (diameter at breast height, 1.30m), d7 (diameter at 7 meters height), total height and crown parameters. Furthermore, auxiliary data on the structure and status of the forest, the SP-location and its topographic characteristics as well as on possible human induced impacts were collected. Data on young forest or regeneration were obtained on special plots (small squares in Figure 4).

POST-STRATIFICATION. Using the data of the entity of sample plots (dendrometric and auxiliary) a post-stratification was applied to the population. Post-stratifications generally aim

TABLE 3. Description of the three assessment areas.

1: Tsinjoarivo (TJV)	2: Manompana (MPA)	3:Tsimanampetsotsa (TMP)
Semi-decidous rainforest located in the 'Haute Plateau' of Madagascar	Wet rainforest at the east-coast of Madagascar	Dry forest in the south-west of Madagascar
Total area: 32,272 hectares	Total area: 46,095 hectares	Total area: 43,296 hectares
In-situ assessment from October to November 2007	In-situ assessment from April to May 2008	In-situ assessment conducted from September to October 2008

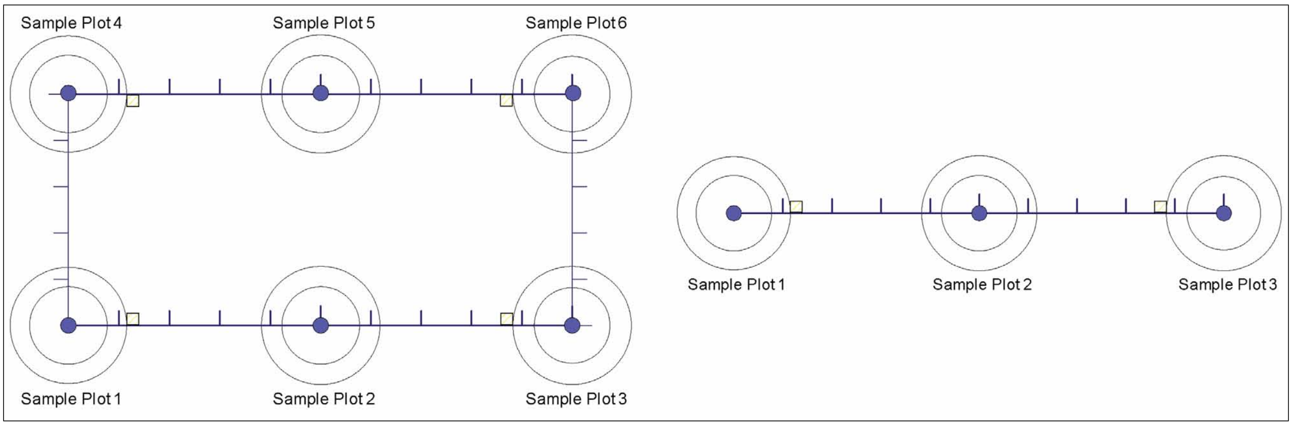

FIGURE 4. Cluster layouts applied in the REDD project in Madagascar; left for nearly pristine forests; right for highly fragmented forests. Distances between sample plots and sample plot size may also be adapted.

at producing sampling estimates with a lower sampling error for each stratum. While strata are physically connected, domains can be described as groups with specific characteristics that are found throughout the whole population, i.e., members of different domains can be found on one single SP. In the presented survey a distinction between different domains was achieved.

Nevertheless, a valid post-stratification is depending on the discriminability of the collected and examined data and can not be forced. Hence, this step is not an indispensable prerequisite for the following.

ABOVEGROUND BIOMASS. The combined inventory focuses on the calculation of living aboveground biomass (AB). There are numerous ways to derive AB depending on the scale of the inventory, i.e., local, regional, or national, or the data available for a specific scale (Köhl 1998, IPCC 2006, Somogyi et al. 2007).

In the presented study, single tree volume was derived via segmentation of each tree and the appliance of domain-specific taper functions. The tree was divided into three parts: main stem (bole), the top, and the stump section. While the stump and the top represent just one single segment, the bole itself can have multiple segments, each with a different taper. Calculation of the volume of each part is presented here for the example of the second assessment area, but was similarly done in the other assessment areas with alterations regarding the area specific domains.

Volume of the bole (V_{bole}):

$$V_{bole} = \sum_{s=1}^{n} \left(\frac{\pi * l_{Sn} * d_{Sn}^2}{12} \right) + \left(\frac{d_{Sn} * d_{Sn+1}}{4} \right) + \left(\frac{d_{Sn+1}^2}{4} \right)$$

with

$$d_{Sn+1} = d_{Sn} * \left(\frac{100 - e^{\alpha + \frac{\beta}{d_{Sn}}}}{100} \right)$$

with

α and β = domain-specific parameters

d_{Sn} = diameter at the beginning of segment n

d_{Sn+1} = diameter at the end of segment n

l_{Sn} = length of segment n

Volume of the top (V_{top}):

$$V_{top} = \left(\frac{\pi * d_{Sn}^2 * (h_{tot} - h_{bh} - n_s * l_s)}{12} \right)$$

with

h_{tot} = total height of the tree

n_s = number of segments of the tree

h_{bh} = breast height

Volume of the stump (V_{stump}):

$$V_{stump} = \left(\frac{h_{bh}}{4} \right) * \left(\left(\frac{\pi * d_{Sn-1}^2}{4} \right) + \left(\left(\frac{\pi * d_{Sn-1}}{4} \right)^2 * \left(\sqrt[3]{\frac{\pi * d_{Sn}^2}{4}} \right) \right) + \left(\left(\frac{\pi * d_{Sn}}{4} \right)^2 * \left(\sqrt[3]{\frac{\pi * d_{Sn-1}^2}{4}} \right) \right) + \left(\frac{\pi * d_{Sn}^2}{4} \right) \right)$$

with

$$d_{Sn-1} = \frac{d_{Sn}}{\left(\frac{100 - e^{\alpha + \frac{\beta}{h_{bh}}}}{100} \right)}$$

with

α and β = domain-specific parameters

d_{Sn-1} = diameter on ground level

The aboveground biomass of a single tree (AB_{tree}) was derived using the above formulas as an input for:

$$AB_{tree} = \left(V_{stump} + V_{bole} + V_{top} \right) * BF$$

with:

BF = species specific biomass factor.

The species specific biomass factor (BF) was taken from existing literature, such as Brown (1997) or IPCC (2006). Otherwise default values for tropical hard- or softwoods provided by IPCC (2006) have been applied.

Conversion of biomass into carbon can likewise be done by means of equation factors. The more specific these equation factors are for different regions, the more elaborate the results will be. If no detailed information is available or the collection of a reasonable number of samples for wood density is too laborious, IPCC (2006) provides default values to convert biomass into carbon.

UPSCALING PROCEDURES. The aboveground biomass (AB) for a single tree was obtained by the equations described above. The sum of the AB for all trees of one sample plot (SP) results in the total AB for this SP. The sum of all SPs of one cluster as well as the associated variance and sampling error are derived on the basis of the single tree values. This holds as long as the cluster size is kept constant. Procedures to derive variances and sampling errors for unequal cluster sizes are described in Cochran (1977). Upscaling procedures expand cluster data to area related estimates resulting in an aggregation of the respective values, variances, and errors on different scales (e.g., forest fragments, strata, or country). Details of the applied upscaling procedures are described in Riedel (2008). After appliance of these procedures sound and sensitive estimates of forest biomass were derived.

QUANTIFYING THE AMOUNT OF REDUCED CO_2 EMISSIONS.

Quantification of the amount of reduced CO_2 emissions is essential to any country that wants to commit itself to a REDD regime. This includes two important components: (1) There has to be a reference level (i.e., a baseline), against which the changes of carbon stocks in forests are set off. Different possibilities for the construction of reference scenarios are given in the specific literature (Griscom et al. 2009, Krug et al. 2009). (2) There has to be a monitoring of the development of the carbon stocks. This is provided by the presented methodology. The amount of reduced emissions can then be derived with the difference between the assumed carbon stock at the end of the commitment period referring to the selected reference level and the carbon stock estimation derived from the applied methodology.

RESULTS

Based on the IPCC categories for the zone 'Tropical Forests' a stratification in 'wet', 'intermediate' and 'dry' was achieved using a forest cover change detection algorithm (see section Regionalisation of the land area of Madagascar) and for each strata an assessment area was identified (see Table 3 and Figure 3). Combined inventories were carried out in all three assessment areas. The following table (Table 4) presents the results for the assessment areas, derived with the above described methodology. Three different domains were identified, i.e., 'Closed Forest' (crown cover ≥ 20 %), 'Open Forest' (crown cover ≥ 10 % and < 20 %) and 'Non Forest' (crown cover < 10 %). The estimated means of the first two domains were tested for statistical significant differences on the 95 % confidence level using a t-test. Furthermore, these estimates are combined in the domain 'Forest total'. As only clusters within forest or forest fragments were included in the field survey, there is no further terrestrial information on the domain 'Non Forest' assuming that there is no considerable amount of biomass.

For the Tsinjoarivo assessment area (see Figure 3, No. 1), the values for the mean aboveground biomass (AB) for 'Closed Forest' and 'Open Forest' are not significantly different (190.3 to 154.0 t / ha) from each other. The area fraction for 'Closed Forest' is small; the intra-cluster-correlation coefficients (ICCs) for all domains of this assessment area are relatively high. The 'Non Forest' area is disproportionately high. The estimate for mean AB for the combined domain 'Forest total' is 163.7 t / ha.

For the assessment area of Manompana (see Figure 3, No. 2) the differences between the mean AB of 'Closed Forest' (293.2 t / ha) and 'Open Forest' (184.0 t / ha) are significant. The amount of sample plots in 'Closed Forest' is considerably higher than in 'Open Forest'. The ICC ranges from 0.18-0.28. The 'Non Forest' area accounts for 25 % of the total area. The resulting estimate for 'Forest total' is 272.5 t / ha.

The mean AB in the domain 'Closed Forest' in Tsimanampetsotsa (see Figure 3, No. 3) is 136.1 t / ha and significantly different to the estimate for the domain 'Open Forest' (mean AB 87.7 t / ha). More than one third of the sample plots is in the domain 'Non Forest'. The ICC ranges from 0.15-0.32. The estimate for 'Forest total' in Tsimanampetsotsa is 98.9 t / ha.

TABLE 4. Estimates for each of the three assessment areas.

Domain	n_SP	AF (ha)	SE of AF (%)	AB total (t)	SE of AB total (%)	Mean AB (t / ha)	SE of mean AB (%)	ICC
Tsinjoarivo								
Closed Forest	15	495	31.0	94,169	31.7	190.3	34.2	0.72
Open Forest	41	1,353	18.9	208,302	19.8	154.0	23.7	0.73
Forest total	56	1,848	19.0	302,471	20.0	163.7	23.9	0.78
Non Forest	922	30,424	1.2					
Manompana								
Closed Forest	47	28,136	12.4	8,250,251	13.1	293.2	29.5	0.27
Open Forest	11	6,585	32.4	1,211,540	32.0	184.0	43.0	0.18
Forest total	58	34,721	9.4	9,461,790	10.2	272.5	25.5	0.28
Non Forest	19	11,374	28.8					
Tsimanampetsotsa								
Closed Forest	21	6,448	23.8	877,889	27.5	136.1	34.7	0.22
Open Forest	70	21,494	9.1	1,885,991	9.5	87.7	23.0	0.15
Forest total	91	27,943	8.7	2,763,880	11.6	98.9	18.5	0.32
Non Forest	50	15,353	15.9					

n_SP = number of sample plots; AF = area fraction; SE = standard error; AB = aboveground biomass; ICC = Intra-Cluster-Correlation-Coefficient; t = ton; ha = hectar

TABLE 5. Aggregation of estimates on country level.

Madagascar							
Domain	n_SP	AF (ha)	SE of AF (%)	AB total (t)	SE of AB total (%)	Mean AB (t / ha)	SE of mean AB (%)
Closed Forest	83	35,079	10.9	9,222,309	12.0	262.9	26.6
Open Forest	122	29,432	9.9	3,305,832	13.0	112.3	20.6
Forest total	205	64,512	6.4	12,528,141	8.2	194.2	20.1
Non Forest	991	57,151	7.2				
n_SP = number of sample plots; AF = area fraction; SE = standard error; AB = aboveground biomass; t = ton; ha = hectar							

Table 5 shows the aggregation of the estimates for the three assessment areas as presented above on country level for Madagascar. Consequently the apportionment into three domains ('Closed Forest', 'Open Forest', 'Non Forest') and the combination of 'Closed Forest' and 'Open Forest' as 'Forest total' again is applied. For the aggregation on country level no ICC as a measure of the efficiency of cluster sampling is calculated, because sensible results can only be expected for the assessment area level.

The estimates for 'Closed Forest' (262.9 t / ha) and 'Open Forest' (112.3 t / ha) on national scale are significantly different from each other. The estimate for mean aboveground biomass for the combined domain 'Forest total' is 194.2 t / ha. The overall sampling error (SE of mean AB) ranges from 26.6 % to 20.1 % decreasing with increasing sample size.

DISCUSSION

The applied methodology displays the adaptation of fully operational and respected methods to the particular needs of a possible REDD regime for Madagascar. The application of remote sensing analyses for the top-down approach using medium resolution imagery and sensible auxiliary data forthe regionalisation of the land area of Madagascar and a first stratification into forest and non-forest areas proved to be feasible. The identification of hot spots of deforestation utilizing change detection analysis with different points in time led to a sound and sensible selection of appropriate assessment areas. A further stratification of these areas e.g., into the strata closed forest and open forest, could have been possible by means of very high resolution imagery. However, this was not feasible in this project due to disadvantageous RS-data quality. Nevertheless, utilizing expensive, very high resolution imagery not for the entire country but only for the identified assessment areas helps to keep costs at a manageable level.

The systematic sampling approach incorporating cluster sampling for the in-situ assessment proved to be operational for remote and hard to access as well as highly fragmented forest areas. The physical conduction of the in-situ method and the subsequent calculation of single tree biomass as well as the applied upscaling methods led to sound and reliable estimates on aboveground biomass for each of the assessment areas which are discussed in the following.

ESTIMATES FOR THE THREE ASSESSMENT AREAS. The non-significance in the difference of the estimates for mean aboveground biomass (AB) (see Table 4) in the assessment area Tsinjoarivo as well as the high intra-cluster-correlation coefficient (ICC) is caused by the high fragmentation and degradation of the forest. The high amount of sample plots in the domain 'Non Forest' is owed to the same reason and enhanced by the fact that at the time of planning only outdated data from the national forest inventory (NFI) from 1996 were available as reference. This resulted in a conservative layout of the sampling grid (1 km x 2 km). The estimate for the combined domain 'Forest total' meets the IPCC values for the adapted category 'intermediate (semi-dry / semi-wet)' forests (see Table 2).

The ICC for the assessment area Manompana is justifiable in the scope of a pilot project. The estimate for the domain 'Forest total' is within the range of possible values for the adapted IPCC category 'wet' (310 to 272.5 t / ha). The sampling error could be reduced significantly if the applied method would be adjusted to a national scale inventory, thus augmenting the sampling intensity in this category.

The ICC in the assessment area of Tsimanampetsotsa is acceptable for a pilot project. The estimate for the adapted IPCC category is well within the range of possible values (see Table 2). The error of the estimates in this area is also acceptable for a pilot project.

The estimate aggregated on country level for the domain 'Forest total' (194.2 t / ha) meets the default value for aboveground biomass content in forest in 2000 given by IPCC in table 3A.1.4 of the GPGLULUCF for Madagascar (194 t / ha) (IPCC 2003). The sampling error for the mean AB in this domain is acceptable for a pilot project but is likely to be reduced if the applied assessment scheme would be extended on a national scale. This would imply an extension of the in-situ assessment to more than the three selected assessment areas, resulting in higher costs for the combined inventory.

RELIABILITY OF ESTIMATES. The assessment of carbon stock and carbon stock changes is associated with uncertainties. The IPCC GPG LULUCF (IPCC 2003) addresses this problem by offering parties to use three different tiers (i.e., levels of reliability) for their national greenhouse gas reporting. Where parties want to generate carbon credits by participating in REDD, the reliable minimum estimate (RME) for carbon stock changes needs to be presented in order to follow the broadly accepted principle of conservativeness (Grassi et al. 2008). A point estimate of the carbon stock or its change rate over time needs to be supplemented by a quantitative measure of its reliability. The point estimate is reduced by the reliability measure resulting in the RME; not the point estimate but the RME qualifies for accounting. Therefore parties are obliged to report on the errors associated with any carbon estimate and need to implement assessment methods that result in estimates with high reliability to render possible the generation of benefits from REDD (Köhl et al. 2009). The reliability of forest area changes is quantified via the accuracy of remote sensing classifications, while the reliability of biomass estimates results from the calculation of sampling error estimates. Errors associated with the assessment of individual tree biomass and its conversion into carbon contents are to be obtained by empirical studies. All different error sources can be combined via an error budget (Gertner and Köhl 1992) and allow for a consistent and accepted quantification of the reliability of carbon stocks and carbon stock changes.

COMBINATION OF REMOTE SENSING DATA AND IN-SITU ASSESSMENTS. The use of satellite imagery and remote sensing techniques has been widely described as an efficient tool to monitor forest area changes (Bowden et al. 1979, UN-ECE/FAO 2000). Remote sensing provides spatially explicit data on forest areas and allows for multi-temporal approaches on forest area changes and can thereby be used in the scope of REDD (GOFC-GOLD 2009).

Apart from detectable and quantifiable deforestation in the applied remote sensing phase the applied in-situ methodology-allows to gather sensitive information on forest degradation, as well. The importance of including degradation in REDD is stated in international discussions (UNFCCC 2008).

Variable extents of forest degradation still make its assessment a challenging task (Baldauf et al. 2009, FAO 2009). In addition, optical remote sensing sensors fall short when it comes to the assessment of minor changes in standing woody biomass (Scott and Köhl 1994). Especially in natural forests in the tropics and subtropics, which are characterised by heterogenic vertical stand structures and contiguous canopy covers, degradation can only be detected, when the formerly closed canopy cover is dissolved. Otherwise, if the forest is degraded affecting the canopy cover in a minor extent only, the degradation remains stealthy for optical remote sensing sensors (see Figure 5). So far, this stealthy degradation can only be assessed by field surveys.

Although clear definitions of degradation are yet missing, the applied methodology is designed to be flexible enough for adaptation to a finally agreed definition of forest degradation.

CONCLUSION

On the one hand the applied methodology depends largely on capacities which have to be available or which have to be build up in a country applying for REDD. Not later than at the end of the first commitment period all capacities should be available in the specific country so that there is no urgent need for broad scale consultancy. On the other hand country specific knowledge is indispensable when generating such an approach. The applied methodology was developed in close collaboration of the Forest Institute of the University of Antananarivo (ESSA Forêts) and the Institute for World Forestry at the vTI in Hamburg, thus guaranteeing the incorporation of country specific knowledge.

A broadly accepted challenge lies in the most effective combination of remote sensing and terrestrial inventories. For the RS-data and further additional data, e.g., national forest inventory (NFI), data availability will differ from country to country. Therefore, the applied methodology uses RS-data that is available worldwide, e.g., MODIS, or identifies sensor categories, i.e., medium, high and very high resolution data.

The results of this pilot study show that the applied combined inventory and the upscaling methods are capable of producing reliable results on a national level. Regarding the need for successive inventories in the scope of REDD the in-situ design can be further optimised for each of the adapted IPCC categories on the basis of the presented results to fully exploit the advantages of a systematic stratified cluster sampling design.

Concerning the detection of degradation areas, problems arise from the small scale differences in RS-data. The availability of cloudless very high resolution data can be considered as a big challenge, especially in the tropics. Presently, there are some projects using high resolution RADAR data (i.e., TerraSAR-X), which could possibly overcome these challenges.

CONTRIBUTIONS & ACKNOWLEDGEMENTS

DP, TB and MK developed the methodology and statistical background aligned to it. DP carried out the terrestrial implementation of the methodology, TB conducted the remote sensing analyses. HRR and GR adapted the methodology to the specific conditions found in Madagascar.

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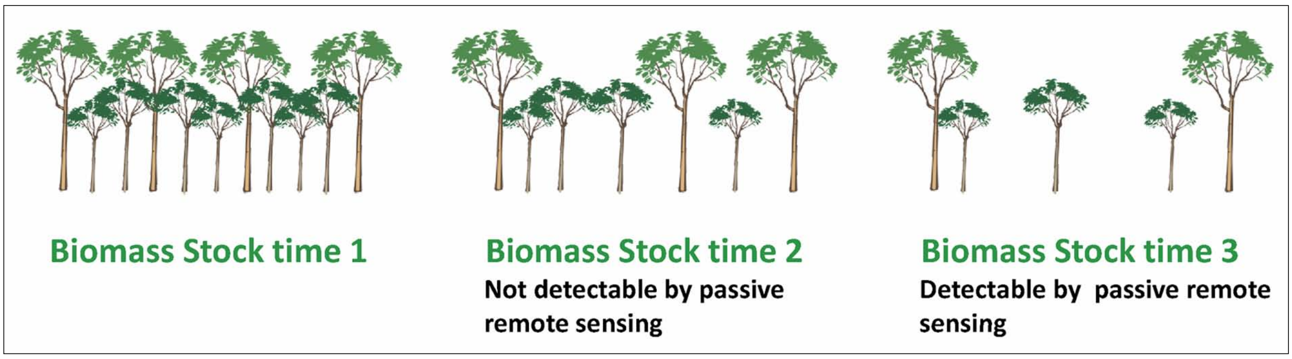

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SUPPLEMENTARY MATERIAL.

AVAILABLE ONLINE ONLY.

Overview of methodology of combined inventory, detailed illustration of the applied combined inventory methodology showing the top-down and bottom-up approaches.

Protected area surface extension in Madagascar: Do endemism and threatened species remain useful criteria for site selection ?

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ABSTRACT

The 'hotspot approach' considers that endemism and threatened species are key factors in protected area designation. Three wetland and forest sites have been proposed to be included into Madagascar's system of protected areas (SAPM – *Système des Aires Protégées de Madagascar*). These sites are Manambolomaty (14,701 ha) and Mandrozo (15,145 ha) in the west and Bemanevika (37,041 ha) in the north. Biodiversity inventories of these three sites recorded 243 endemic species comprised of 44 reptiles, 54 amphibians, 104 birds, 23 small mammals, 17 lemurs and one fish. Of these 243 species, 30 are threatened taxa comprising two Critically Endangered (CR), 11 Endangered (EN) and 17 Vulnerable (VU) species. The long term ecological viability of these sites has been shown by population stability of the two Critically Endangered flagship species, the Madagascar fish eagle (*Haliaeetus vociferoides*) in Manambolomaty and Mandrozo and the recently rediscovered Madagascar pochard (*Aythya innotata*) in Bemanevika. Other threatened species and high biological diversity also justifies their inclusion into Madagascar's SAPM.

RÉSUMÉ

L'endémisme et les espèces menacées constituent les éléments clef pour la création des aires protégées. Trois zones humides de Madagascar ainsi que leurs forêts avoisinantes sont proposées pour la protection sous le nouveau système des aires protégées malgaches connu sous le sigle SAPM (Système d'Aires Protégées de Madagascar) : Manambolomaty (14.701 ha) et Mandrozo (15.145 ha) à l'Ouest et Bemanevika (37.041 ha) dans le Nord. Les inventaires biologiques entrepris dans ces trois sites ont montré que 243 espèces y sont endémiques, avec 44 reptiles, 54 amphibiens, 104 oiseaux, 23 petits mammifères, 17 lémuriens et un poisson. Parmi ces 243 espèces, 30 sont menacées d'extinction avec deux qui sont en danger critique d'extinction (CR), 11 en danger (EN) et 17 vulnérables (VU). La survie écologique à long terme de ces sites a été avérée avec la découverte de la stabilité des populations des deux espèces indicatrices en danger critique d'extinction que sont le Pygargue de Madagascar (*Haliaeetus vociferoides*) à Manambolomaty et Mandrozo et une espèce récemment redécouverte, le Fuligule de Madagascar (*Aythya innotata*) à Bemanevika. La stabilité de plusieurs autres espèces menacées ainsi que la diversité biologique de ces sites justifient leur inclusion dans le SAPM. Les sept associations locales, deux à Manambolomaty, deux à Bemanevika et trois à Mandrozo, ont supporté le programme de suivi de ces sites ainsi que de ces espèces indicatrices en montrant ainsi leur engagement dans le processus de création des aires protégées. Le Peregrine Fund a travaillé dans ces sites en vue de mettre en synergie ses objectifs de conservation avec le développement socio-économique local.

KEYWORDS: SAPM, flagship species, Bemanevika, Mandrozo, Manambolomaty.
MOTS CLEFS : SAPM, espèces indicatrices, Bemanevika, Mandrozo, Manambolomaty.

INTRODUCTION

Madagascar's human population is estimated at 19 million, with more than 70 % living in rural areas where they are entirely dependent on local natural resources for their livelihood, which has a great impact on biodiversity (Primack 2002, Brown 2007). Madagascar is one of eight important global biodiversity hotspots owing to its unique biota and the high degree of threat to its natural habitats (McNeely et al. 1990, Myers et al. 2000, Ganzhorn et al. 2001, Mittermeier et al. 2005). Unsustainable use of natural resources through slash-and-burn agriculture, cutting trees for fuel, clearing land for zebu grazing, hunting and fishing are considered the main reasons for loss of biodiversity and degradation of natural habitats in Madagascar (Messerli 2000, Primack 2002, Benstead et al. 2003, Mittermeier et al. 2005).

Since the 1980's, national and international efforts to preserve Madagascar's biodiversity have been significant (Mittermeier et al. 2005). Currently, under the Madagascar National Parks management (MNP formerly known as ANGAP = *Association Nationale pour la Gestion des Aires Protégées*), there are over 50 protected areas in Madagascar divided into Strict Nature Reserves (IUCN category I), National Parks (IUCN

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category II) and Special Reserves (IUCN category IV) (Nicoll 2003, Mittermeier et al. 2005). MNP's primary objective is to have representation of Madagascar's various ecosystems and maintain the island's unique biodiversity (Nicoll 2003). The current protected area network covers some 1.7 million hectares or about 3 % of the country (Mittermeier et al. 2005). However, recent gap analysis reveals, as for many protected areas in the world (Oldfield et al. 2004, Rodrigues et al. 2004), that the coverage of Madagascar's unique biodiversity by this network is far from adequate and requires a significant increase in protected area coverage (Mittermeier et al. 2005). There is a high risk of extinction of several newly described, endemic and threatened species outside of Madagascar's present network of protected areas (Andreone et al. 2001, Raxworthy and Nussbaum 2006, Rene de Roland et al. 2007, Sparks and Stiassny 2010). In 2003, the fifth World's Park Congress was held in Durban, South Africa. During the meeting, Madagascar's president recognized the value of protecting the country's unique natural heritage and stated his commitment to a national conservation plan that would triple the amount of protected area coverage (Mittermeier et al. 2005).

Cabeza and Moilanen (2001) stated that current strategies for designing a reserve are to maximize the number of species conserved within a minimum loss of habitat and land. This concept may lead sometimes to the issue of under representation of keystone species, those which are threatened and in need of strict protection (Kati et al. 2004, Oldfield et al. 2004), but it is clear that protection *in situ* remains the greatest hope for global conservation of biodiversity (Pressey 1996, Margules et al. 2002, Chape et al. 2005). This paper aims to present the importance of the three newly proposed Malagasy protected sites based on inventories of species, comparing the sites in terms of endemism and threatened taxa and monitoring of flagship species to show these sites are ecologically stable and justifiable for their inclusion into Madagascar's network of protected areas.

STUDY AREA AND METHODS

THREE PROPOSED SITES. The Malagasy government is presently working to add three more IUCN categories to Madagascar's newly protected areas system known as SAPM (Système des Aires protégées de Madagascar). These categories are Natural Monument (IUCN category III), Protected Landscape / Seascape (IUCN category V) and Reserve of Natural Resources (IUCN category VI). For this purpose, we have proposed three new potential protected sites, Manambolomaty, Mandrozo and Bemanevika, into Madagascar's protected area network in Madagascar's commitment in conserving its unique biodiversity and natural heritage (see Figure 1). Manambolomaty is located in central western Madagascar, in the communes of Masoarivo and Trangahy, District of Antsalova, Region of Melaky (E44° 26', S19° 01') at seven meters of elevation. The Manambolomaty site is composed of four major lakes and part of the Tsimembo dry deciduous forest. On average, the lakes are 3 - 5 m deep with a maximum depth of five meters recorded at the end of the rainy season. In 1998, Manambolomaty was the first RAMSAR site in Madagascar. This site includes Soamalipo and Befotaka Lakes in the Masoarivo Commune and Ankerika Lake in the Trangahy Commune, for a total area of 14,701 ha of wetland and dry deciduous forest. The Manambolomaty Lakes complex is

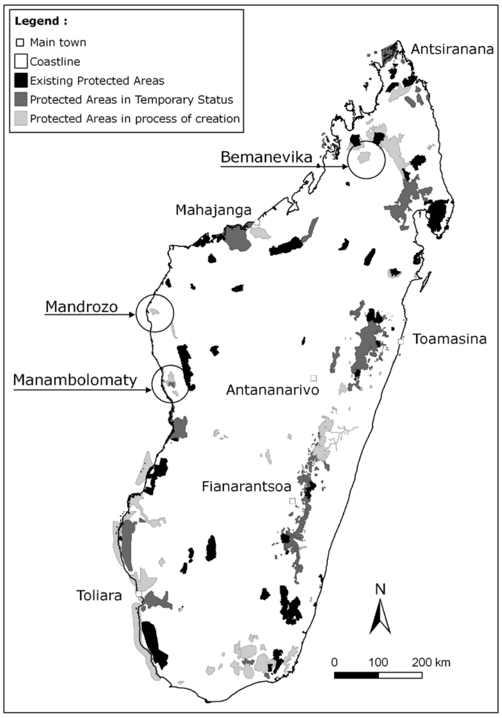

FIGURE 1. Map of the proposed SAPM sites of Manambolomaty, Mandrozo, and Bemanevika in Madagascar.

of natural origin and fed by the Manambolomaty River during the rainy season. The climate is characterized by a dry warm season extending from April to October and a hot rainy season from November to March. The annual rainfall varies from 499 - 1,193 mm (see Table 1) and the temperature ranges from 15 - 37 °C (Razafimanjato et al. 2007). The dominant trees within the Tsimembo forest are *Dalbergia* sp. (Fabaceae), *Delonix* sp. (Fabaceae) and *Cordyla madagascariensis* (Fabaceae), which are approximately 12 m in height with a few emergent trees reaching up to 20 m.

Mandrozo is a wetland site located within the three communes Veromanga, Andranovao and Tambohorano, District of Maintirano, Melaky Region, western Madagascar (E44° 05', S17° 32'), and is approximately 280 km north of the Manambolomaty site. Mandrozo Lake has a surface area of 1,800 ha, and like many other lakes in western Madagascar it is fairly shallow with an average depth of 2 - 3 m (reaching up to over five meters during the rainy season). Rainfall data are lacking for this site, but due to similar seasonal variations, should be similar to the Manambolomaty site. It encompasses 15,145 ha, including Mandrozo Lake and the surrounding dry fragmented deciduous forest interspersed with palm forests and grasslands, and the elevation ranges from 7 - 60 m. The forest habitat is composed mainly of *Millettia richardiana* (Fabaceae), *Trilepisium madagascariense* (Moraceae) and *Drypetes perrieri* (Euphorbiaceae), which reach 6 - 10 m in height. The

TABLE 1. Annual rainfall at Manambolomaty Lakes Complex in western Madagascar from 2002, 2003, 2005 - 2007.

Year	Rainfall [mm]
2002	499
2003	1106
2005	1006
2006	1082
2007	1193

endemism rate for plants in Mandrozo is approximately 76 % (The Peregrine Fund 2008a).

Bemanevika is located within two communes Antanagnivo-Haut and Beandrarezona, District of Bealanana, Sofia Region, northwestern Madagascar (E48° 32', S14° 22'), and covers an area of 37,041 ha. The topography is variable and comprises a mixture of valleys and mountains ranging from 700 - 1,800 m in elevation. The habitat types are heterogeneous and are composed mainly of five permanent lakes (Andriakanala, Maramarantsalegy, Matsaborimena, Matsaborimaitso and Matsaborimisivoay) with a total surface area of 150 ha, large patches of fragmented rainforest, several marshes, and expansive grasslands. The lakes are volcanic in origin with Matsaborimena the shallowest and Andriakanala the deepest, with maximum depths of two meters and 83 m, respectively. The climate is tropical and humid, with annual precipitation ranging from 1,600 - 2,700 mm (Donque 1975). The rainy and dry seasons are the same as for the two previous sites, however, the temperature ranges from 10 - 30 ° C, and can dip below 10 ° C during the coldest period in July. The mature primary rainforest has a canopy ranging from 12 - 20 m, and is composed mostly of the following trees: *Malleastrum rakotozafyi* (Meliaceae), *Weinmannia rutenbergii* (Cunoniaceae), *Plagioscyphus jumellei* (Sapindaceae), *Syzygium emirnense* (Myrtaceae), *Macphersonia gracilis* (Sapindaceae), *Filicium longifolium* (Sapindaceae), *Calophyllum milvum* (Clusiaceae) and *Tambourissa* sp. (Monimiaceae).

DATA COLLECTION. Rapid Biological Assessment: In Bemanevika (December 2007 to January 2008) and Mandrozo (March to April 2008) rapid biological inventories of reptiles, amphibians, and birds were completed, but we were unable to inventory small mammals and lemurs at the Mandrozo site and fishes in Mandrozo and Bemanevika due to time and financial constraints. For ecological heterogeneity, these faunal groups we surveyed have been used for small - scale reserve designation (e.g., Kati et al. 2004). Four specific sites (Matsaborimena - Matsaborimaitso, Andriakanala, Morapitsaka and Matsaborimisivoay) were surveyed at Bemanevika and two (Analalava and Antsakoamalinika) at Mandrozo. Several types of inventory methods were used in order to assess the biodiversity of the proposed sites. Direct diurnal and nocturnal observations were made for all inventoried faunal groups.

For herpetofaunal surveys, refuge examination and pitfall traps were used. Refuge examination required researchers to search under leaf litter and rocks among dead wood, leaf axils of *Pandanus* palms, and on tree trunks during the day and night to record species (Raxworthy 1988, D'Cruze et al. 2007, 2008). Pitfall traps consisted of buckets (15 liters in volume) with handles removed dug into the ground and placed at 10 m intervals along a drift fence 100 m in length. The buckets were drilled with small holes in the bottom to allow water to drain (for more information on pitfall protocol, see Raxworthy 1988, Rakotomalala and Raselimanana 2003). At each specific site, traps were checked twice a day at 0600h and 1600h during six consecutive trap days. No voucher specimen was taken from Mandrozo. Specimens from Bemanevika (research permit N° 0295/07/MINENV.EF/SG/DGEF/DPSAP/SSE) were stored in 70 % ethanol solution and housed in the laboratory of Animal Biology Department at the University of Antananarivo (Appendix 1).

Forest birds were directly counted using the Mackinnon and Phillips (1993) species - list approach. Researchers walked slowly (about 1 - 1.5 km per hour) along pre - existing trails and recorded bird species encountered or heard. To maximize species encountered, observations were conducted from 0430 - 0830h when birds were most active and vocal (Scott et al. 1981). Waterbirds were surveyed from observation points along lakeshores following the 'Look and See Method (opportunistic sighting)' by Bibby et al. (1998) using binoculars and spotting scopes. This direct observation technique (Perennou 1991) has been used by several researchers in western Madagascar for waterbird surveys and monitoring (e.g., Razafimanjato et al. 2007).

For mammal surveys, pitfall traps were used for small terrestrial mammals (Stephenson 1993, Soarimalala and Goodman 2003). Sherman live traps were also used to capture small mammals, and traps were baited with peanut butter and the distance between two consecutive traps varied according to the habitat. To maximize small mammal inventories traps were set on the ground, on decomposing trees, under tree roots, on tree trunks, dead leaves or leaf litter and along the river and / or lake shore. Pitfall and Sherman traps were checked twice a day at 0600h and 1600h.

Literature review consists of compiling the available biological field data and is often used to support the biodiversity conservation strategies (Carpenter and Robson 2005). For faunal groups not inventoried during this study at Manambolomaty, species lists for lemurs, fishes and waterbirds were taken from Razanantsoa (2000), Rasamoelina (2000), and Razafimanjato et al. (2007), respectively.

Threatened Species and the International Union for Conservation of Nature (IUCN) Redlist: Information from the literature was used to determine species endemism in Madagascar (e.g., Reinthal and Stiassny 1991, Goodman et al. 2003, Hawkins and Goodman 2003, Raselimanana and Vences 2003, Sparks and Stiassny 2003, 2008). Each species was checked for its current population status from the IUCN 2008 Redlist to determine if it is Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC) or poorly known Data Deficient (DD). For conservation priority purpose, emphasis was given to those species listed in the three highest IUCN threat categories: CR, EN and VU (Raxworthy and Nussbaum 2000, Andreone et al. 2005a), although all IUCN categories were considered.

Flagship species monitoring: For long - term management objectives, two avian species sensitive to environmental change, the critically endangered Madagascar fish eagle (*Haliaeetus vociferoides*) (Watson et al. 1996, 2007, Watson and Rabarisoa 2000) and Madagascar pochard (*Aythya innotata*) (Rene de Roland et al. 2007) were monitored and used as indicator species to assess the environmental health of each site. In Manambolomaty and Mandrozo, Madagascar fish eagles were monitored following the survey methods described by Rabarisoa et al. (1997) and Watson et al. (2007). Each occupied nest was visited three times during the breeding season: Egg laying, nestling and dispersal periods to determine productivity (for more details see Rabarisoa et al. 1997 and Watson et al. 2007). In Bemanevika, for the critically endangered Madagascar pochard, surveys were conducted monthly at four of the five lakes by four teams composed of two persons per team. Each team counted the number of pochards observed every 10 minutes from 0600 - 1800h. Currently, the Bemanevika area is the only known and maybe the only viable site for this critically endangered duck in Madagascar (Rene de Roland et al. 2007).

RESULTS

ENDEMISM AND THREATENED SPECIES STATUS. Of the 16 species of fishes recorded in Manambolomaty, only one is endemic to Madagascar, *Arius madagascariensis* (Table 2, Supplementary Material).

For amphibians, the Bemanevika site hosts 48 species, whereas 11 species were recorded at the drier Mandrozo site. In total, 58 species of amphibians were found at both sites of which 54 are endemic. Only one species, the Mascarene ridged frog *Ptychadena mascareniensis,* was found at both sites. The Bemanevika site had one endangered and four vulnerable species: *Scaphiophryne boribory* (EN), *Boophis blommersae* (VU), *Gephyromantis striatus* (VU), *Mantella pulchra* (VU) and *Spinomantis massi* (VU). None of the Mandrozo amphibian species are on IUCN's threatened species list, although the Western white-lipped treefrog *Boophis occidentalis* is considered Near-Threatened (NT).

A total of 57 reptile species were recorded in the Bemanevika and Mandrozo sites. Eighteen were found strictly in Bemanevika whereas there were 36 species in Mandrozo and three species were shared by both sites: Malagasy giant hognose snake *Leioheterodon madagascariensis,* Stripeneck skink *Madascincus intermedius* and Madagascar girdled lizard *Zonosaurus madagascariensis.* The Bemanevika site is richer in chameleon species (n = 5 species) than Mandrozo site (n = 2 species) whereas for other squamates, species richness was higher in Mandrozo than in Bemanevika (Supplementary Material). Combining both sites, a total of 44 endemic species was recorded, and according to the IUCN (2008) two are vulnerable, the Madagascar ground boa (*Acrantophis madagascariensis)* and Madagascar tree boa *(Sanzinia madagascariensis*), and one is endangered, the Madagascar big-headed turtle (*Erymnochelys madagascariensis*). None of the squamates and testudines found at the Bemanevika site are listed in the IUCN (2008) as threatened.

All avian species recorded at Manambolomaty were waterbirds. A comparison for forest bird species is only meaningful

TABLE 2. List of Endangered (EN) and Critically Endangered (CR) species recorded at the three SAPM sites and total number of taxa with endemism. For detailed list of taxa see Supplementary Material.

	Bemanevika	Mandrozo	Manambolomaty	Endemic species	Status IUCN 2008
Fishes					
Total			16	1	4
Amphibians					
Scaphiophryne boribory	*			*	EN
Total	48	11		54	36
Reptiles					
Pelomedusidae					
Erymnochelys madagascariensis		*		*	EN
Total	18	36		44	4
Birds					
Ardeidae					
Ardeola idae	*	*		*	EN
Ardea humbloti		*	*	*	EN
Threskiornis bernieri		*	*	*	EN
Anatidae					
Anas melleri	*			*	EN
Anas bernieri			*	*	EN
Accipitridae					
Eutriorchis astur	*			*	EN
Haliaeetus vociferoides		*	*	*	CR
Rallidae					
Amaurornis olivieri		*		*	CR
Tytonidae					
Tyto soumagnei	*			*	EN
Total	106	91	47	104	160
Micromammals					
Muridae - Nesomyinae					
Brachytarsomys villosa	*			*	EN
Total	25			23	22
Lemurs					
Indridae					
Avahi occidentalis			*	*	EN
Total	8		10	17	13

between Mandrozo and Bemanevika. Altogether, 161 avian species were recorded at the three sites, of which 106 were in Bemanevika, 91 in Mandrozo and 47 in Manambolomaty (waterbirds only) and 75 species were in common at least for two sites. In total, 104 endemic species were recorded at the three sites. At the Bemanevika site nine threatened species were recorded, of which five were waterbirds: Madagascar pochard *Aythya innotata* (CR), Meller's duck *Anas melleri* (EN), Madagascar pond heron *Ardeola idae* (EN), Madagascar rail *Rallus madagascariensis* (VU) and Madagascar little grebe *Tachybaptus pelzelnii* (VU), and four were forest birds: Madagascar serpent-eagle *Eutriorchis astur* (EN), Madagascar red owl *Tyto soumagnei* (VU), Madagascar harrier *Circus macrosceles* (VU) and Bernier's vanga *Oriolia bernieri* (VU). At Mandrozo, five threatened species were recorded: Madagascar fish eagle *Haliaeetus vociferoides* (CR), Sakalava rail *Amaurornis olivieri* (EN), Madagascar heron *Ardea humbloti* (EN), Madagascar pond heron *Ardeola idae* (EN) and Madagascar white ibis *Threskiornis bernieri* (EN). Manambolomaty has six threatened species: Madagascar fish eagle (CR), Madagascar teal *Anas bernieri* (EN), Madagascar heron (EN), Madagascar white ibis (EN), Madagascar plover *Charadrius thoracicus* (VU) and Madagascar little grebe (VU).

At Bemanevika, 25 small mammal species were recorded of which 23 are endemic, and one is endangered, the poorly known Hairy-tailed tree rat *Brachytarsomys villosa* (EN) (IUCN 2008). For lemurs at Manambolomaty, one species is endangered, the Western avahi *Avahi occidentalis* (EN) and two are vulnerable, Western lesser bamboo lemur *Hapalemur occidentalis* (VU) and Milne-Edward's sportive lemur *Lepilemur edwardsi* (VU). At Bemanevika only one vulnerable lemur species was recorded, the Western grey bamboo lemur (VU) (Mittermeier et al. 2006).

MONITORING OF FLAGSHIP SPECIES. The annual populations for Madagascar pochards and Madagascar fish eagle have remained relatively stable since the beginning of community-based conservation activities (see Table 3). From 2007-2008, the Madagascar pochard's global population has been stable at 18-20 individuals, and is most likely near or at carrying capacity. Displacements from Matsaborimena Lake have been observed, and some individuals have been observed on two other lakes, Andriakanala and Matsaborimaitso. Movement to a small man-made pond in Bemanevika village has been observed too (J. Ramamonjisoa, pers. com.)

TABLE 3. Monitoring of the critically endangered Madagascar Fish Eagle (*Haliaeetus vociferoides*) at Mandrozo and Manambolomaty and the critically endangered Madagascar Pochard (*Aythya innotata*) at Bemanevika.

Site	Monitoring species	Year	Male	Female	Total
Bemanevika	*Aythya innotata*	2007	-	-	20
		2008	-	-	18
Mandrozo	*Haliaeetus vociferoides*	2006	6	6	12
		2007	6	6	12
		2008	5	5	10
Manambolomaty	*Haliaeetus vociferoides*	2002	18	9	27
		2003	18	9	27
		2004	19	11	30
		2005	18	11	29
		2006	20	12	32
		2007	20	11	31
		2008	21	11	32

In Mandrozo, from 2006 to 2008, the population of Madagascar fish eagles remained stable at 10-12 individuals. At the Manambolomaty site, population size of the Madagascar fish eagles varied from 27 to 32 individuals during a seven-year monitoring period (2002 to 2008). At Manambolomaty, about 70-80 % of Madagascar fish eagles' nests contain two males and one female, and in Mandrozo all pairs were one male and one female.

DISCUSSION

LINKING THREATENED TAXA WITH HABITAT VARIABILITY. There is little chance to conserve biodiversity without saving the important habitats for fauna and flora. Failure to include sufficient habitat variation within conserved patches may lead to species extinction in unfavorable years (Kirby 1993). The importance of Madagascar's eastern rainforest in maintaining species diversity is well documented (Raxworthy 1988, Kremen et al. 1999) while western deciduous forests and transitional ecosystems are often overlooked in Madagascar's biodiversity conservation strategy (Ramanamanjato et al. 2002, Rakotomalala 2008, Raselimanana 2008). To fill this gap, the three current SAPM proposed sites will contain varied habitats and ecosystems that are under-represented in today's Madagascar protected area network: Wetlands, deciduous and transitional forests, lakes, and grasslands or wooded grasslands.

The three proposed sites (Manambolomaty, Mandrozo, and Bemanevika) contain at least two important habitats: freshwater lakes and forests. Inclusion of these three sites, which we have documented as being biologically diverse and rich, will help to conserve many threatened taxa and add to the protection of Madagascar's wetland ecosystem. The protection of the Manambolomaty and Mandrozo Lakes will continue to conserve important critical wetland habitat for Madagascar fish eagles within their current range, and about 20 % of the global population based on surveys in 2005 (The Peregrine Fund unpubl. data). The three lakes at the Bemanevika site (Matsaborimena, Matsaborimaitso and Andriakanala) are home to the only known and last viable population of Madagascar pochards (Rene de Roland et al. 2007). Categorized by the IUCN (2008) as critically endangered (CR), these two water-dependant species are listed amongst the world's 189 most threatened birds (Birdlife International 2008). Not including these two critically endangered species, many other threatened waterbirds such as the Sakalava rail *Amaurornis olivieri* (EN), Madagascar teal *Anas bernieri* (EN), Meller's duck *Anas melleri* (EN), Malagasy heron *Ardea humbloti* (EN), Malagasy pond heron *Ardeola idae* (EN), Madagascar sacred ibis *Threskiornis bernieri* (EN), Madagascar plover *Charadrius thoracicus* (VU), Madagascar rail *Rallus madagascariensis* (VU), and Madagascar little grebe *Tachybaptus pelzelnii* (VU), plus the endangered Madagascar big-headed turtle *Erymnochelys madagascariensis* (EN), will benefit from the conservation of these protected wetlands.

The contribution of western and northern forest ecosystems to the conservation of endemic and threatened Malagasy taxa has been previously demonstrated for several species of reptiles (Raxworthy and Nussbaum 1995, 2006, Andreone et al. 2000, 2001), amphibians (Andreone et al. 2000), small mammals (Soarimalala and Goodman 2003) and birds (Seddon and Tobias 2007). Many of these taxa have localized or restricted distributions in unprotected areas (e.g., Andreone et al. 2001, Raxworthy and Nussbaum 2006).

The primary forest cover has declined since 1962, especially in western Madagascar, and by 2000 the annual rate of deforestation has increased, to an estimated 0.93 % per annum (Seddon et al. 2000, Tobias and Seddon 2002). Protecting the two western deciduous forests surrounding the Manambolomaty and Mandrozo Lakes, and the transitional forest in Bemanevika will be beneficial for conservation of Madagascar's natural heritage and biodiversity. The Bemanevika site has a large network of grasslands that are intermixed with marshes, an ecosystem important in protecting too. Fisher and Robertson (2002) highlighted the importance of upland and wooded grasslands in maintaining ant diversity. The critically endangered frog *Mantella aurantiaca* is known as a marsh-dependant species (Zimmermann and Hetz 1992, Zimmermann 1996, Bora et al. 2008). The Madagascar harrier *Circus macrosceles* (VU) also uses marshes for nesting, and it is highly dependent on grasslands and wooded grasslands for foraging habitat (Rene de Roland et al. 2004). Recent surveys throughout Madagascar in 2005 and 2006 recorded the greatest concentration of this vulnerable wetland dependent species at the Bemanevika site (Rene de Roland et al. 2009).

CONSERVATION VALUE OF THE THREE SITES FOR ENDEMICAND THREATENED TAXA. Fishes: Although Stiassny and Raminosoa (1994) recorded only 42 species of freshwater fishes from Madagascar, recent survey work has lead to more than a tripling of this (Sparks and Stiassny 2008). Sparks and Stiassny (2003) listed 143 native (93 endemic) freshwater species, which was recently updated to 159 native freshwater species by Sparks and Stiassny (2008). In Madagascar, three main threats for freshwater fish populations have been identified: Over-fishing, deforestation and introduced species (Reinthal and Stiassny 1991, Benstead et al. 2000, 2003). Sixteen species of fishes have been recorded at the Manambolomaty site, of which one is endemic to Madagascar (*Arius madagascariensis*). *A. madagascariensis* is widespread in the lower reaches of rivers, lakes and estuaries, and is common in western Madagascar (Ng and Sparks 2003a). Malagasy freshwater fish diversity is still very poorly known, and the conservation of threatened taxa is extremely difficult given current threats to aquatic systems (Sparks and Stiassny 2003). For conservation purpose, ichthyological surveys around Mandrozo and Bemanevika regions should be high conservation priorities in Madagascar. For instance, the basins immediately north and south of the Maevarano River Basin, where Bemanevika is situated, supports endemic clupeids, killifish, ariid catfish and cichlids (Loiselle and de Rham 2003a, Ng and Sparks 2003b, Sparks 2003). Moreover, drainages and lakes around Bemanevika may support many species of fishes originally described from the Sofia and Ankofia drainages whose long-term survival is extremely unlikely (Sparks 2003). Owing to the lack of information on fishes in the Bemanevika area, fish surveys are needed for the five permanent lakes (Andriakanala, Maramarantsalegy, Matsaborimena, Matsaborimaitso and Matsaborimisivoay) (J. Rabezandry, pers. com.). For Manambolomaty, *Pachypanchax* species – whose taxonomic status remains to be determined – does occur in several drainages from Antsalova and Manambolo, but is likely absent from the Manambolomaty Lakes (Loiselle and de Rham 2003b). The protection of local forests and the Manambolomaty wetlands will help to assure the integrity of this watershed where this species may occur. Furthermore, the inclusion of this site into Madagascar's protected area network will probably not only reduce the level of threat associated with deforestation, but might also help to overcome the frequent bias in protected area designation in Madagascar, which tends to ignore aquatic diversity (Sparks and Stiassny 2003). However, as protected area creation is a mid- or long-term process (taking at least 3-4 years to obtain definitive protection status), the monitoring of key environmental resources should start early to ensure long-term viability of these proposed sites.

Amphibians and Reptiles: The biodiversity richness of amphibians and reptiles is higher in Bemanevika than in Mandrozo (Table 2, and Supplementary Material). Ramanamanjato et al. (2002) have already highlighted the importance of a transitional forest in maintaining herpetofauna diversity and endemism. Of 48 amphibian taxa found in Bemanevika, five are threatened: One species is endangered, *Scaphiophryne boribory* (EN) and four are vulnerable *Boophis blommersae* (VU), *Gephyromantis striatus* (VU), *Mantella pulchra* (VU) and *Spinomantis massi* (VU). Overall, at both sites, 93 % (54 out of 58) of recorded taxa are endemic (Supplementary Material). Madagascar, as a biodiversity hotspot country, is known for its high endemism of amphibians with 217 known species of which 215 are endemic (Stuart et al. 2004, Mittermeier et al. 2005). The high rate of deforestation and general habitat degradation are the most immediate threats to the amphibian species (Vallan 2002, 2003, Andreone et al. 2005a). It is therefore important to review the current conservation status for the most affected taxa (Andreone et al. 2005a).

Recent global amphibian assessment in Madagascar considered *Scaphiophryne boribory* as an endangered species and one of the taxa at risk of extinction because it has a restricted range where it is found only in a few protected areas (Andreone et al. 2005a, Glaw and Vences 2007). It is also collected for the international pet trade and the impact of this market is mostly unknown (Glaw and Vences 2007). The occurrence of *S. boribory* at Bemanevika extends its range into higher altitude forests, as it is known previously only from sites below 1,000 m (Andreone et al. 2005a). Its threatened status is thus worthy of special attention in defining new protected areas. The 'flagship approach' may be useful for the conservation of *Mantella* frogs and other amphibian species in Madagascar, but the major threats of *Mantella* frogs is the ongoing habitat destruction and exploitation for the international pet trade (Rabemananjara et al. 2005, Andreone et al. 2005ab). They are endemic, colourful and attractive and listed in CITES Appendix II (Glaw and Vences 2007). For example *M. pulchra*, a widely distributed species, is regularly seen in the international markets (Andreone et al. 2005a), but as with other traded amphibian species, studies of the effects of commercial collecting are lacking (Andreone et al. 2005a). The consideration of a *Mantella* site, as supported by Andreone et al. (2005a) may help to conserve the *M. pulchra* in Bemanevika, and other threatened amphibians such as *Boophis blommersae* (VU), *Gephyromantis striatus* (VU), or *Spinomantis massi* (VU).

Of 57 reptiles species found in Bemanevika and Mandrozo, 44 species are endemic, two snake species are vulnerable (*Acrantophis madagascariensis* and *Sanzinia madagascariensis*) and one is endangered, the Madagascar big-headed turtle (*Erymnochelys madagascariensis*). This high endemism of reptiles supports the overall findings that about 91 % of Malagasy reptiles (314 species out of 346) are endemic to the island (Raxworthy 2003a). A recent global survey of biodiversity hot spots found just two other regions, the Caribbean and Meso-America, with a greater reptile species endemism than Madagascar (Myers et al. 2000). Although widely distributed and tolerant of human-habitat modification (Raxworthy and Nussbaum 2000, Raxworthy 2003b), Madagascar's boas *A. madagascariensis* and *S. madagascariensis* remain vulnerable to extinction (Raxworthy 2003b, IUCN 2008). Despite national protection in Madagascar since the 1960s, the three Malagasy boas *A. dumerili, A. madagascariensis* and *S. madagascariensis* are collected commercially for skins and used primarily in the souvenir leather trade (Raxworthy 2003b). They have been listed on The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix I since 1977. Conservation of the Mandrozo site could provide these species a higher level of protection although current impact of commercial collection remains unknown (Raxworthy 2003b). Apparently, the absence of boas in Bemanevika is most likely a result of nearly all the forested and varying habitat being above their altitudinal range of 1,000 m (Raxworthy 2003b). The Madagascar big-headed turtle is a large species, with a carapace up to 50 cm, and is found in the lowlands of western Madagascar between the Mangoky River in the south and the area of Boriziny in the north (Kuchling and Garcia 2003). The Mandrozo site is within its distribution, and it is also known from the Manambolomaty site (Rabearivony et al. 2008). Despite being protected, some individuals are harvested before reaching sexual maturity (Kuchling and Garcia 2003). Currently, the Madagascar big-headed turtle is in a serious noncyclical decline over its whole range (Kuchling and Garcia 2003). It is classified as endangered by IUCN status owing to an estimated population reduction of more than 50 % over the past three generations (Kuchling and Garcia 2003). It is also a key indicator species of clean and open water (Kuchling and Garcia 2003). Its presence at the Mandrozo site indicates that this natural wetland continues to be an important area for preserving this rare freshwater turtle.

The high diversity of chameleon species in the northern region of Madagascar has been well documented (Raxworthy and Nussbaum 1995, 2006, Andreone et al. 2001). Of five chameleon species found in Bemanevika, two are recently described taxa, *Calumma hafahafa* and *C. crypticum* (Raxworthy and Nussbaum 2006). *C. hafahafa* is known to occur only in the Bemanevika area, which contributes to the importance of this site too (Raxworthy and Nussbaum 2006). Near the Bemanevika site at Ambolokopatrika, Andreone et al. (2001) found two local endemic chameleon species *C. vatosoa* and *C. vencesi* and, therefore, claimed the conservation of a long forest corridor between different reserves in the north is urgently needed. Faced with the negative impacts of climate change on Madagascar's biodiversity (Raxworthy et al. 2008), high altitudinal rainforests like Bemanevika could form the last refuge for many herpetofaunal species.

The comparison of Bemanevika and Mandrozo higher reptile diversity to other legally protected areas in Madagascar such as Anjanaharibe-Sud in northern Madagascar, Ampijoroa in northwestern and Tsingy de Bemaraha in midwestern, could also support the inclusion of these two wetland sites into Madagascar's protected area network. Also, Bemanevika with 18 species of reptiles is more diverse than Anjanaharibe-Sud with 13 species, as both are higher elevation sites in northern Madagascar (Rakotomalala and Raselimanana 2003). In western Madagascar, the total reptiles recorded at Ampijoroa (nine species) and Tsingy de Bemaraha (17 species) (Emanueli and Jesu 1995, Schimmenti and Jesu 1997, Mori et al. 2006) are less diverse than those recorded at Mandrozo (36 species) during this study. The discovery of the Neon day gecko *Phelsuma klemmeri* at Mandrozo extended its known distribution approximately 600 km farther south towards mid-western Madagascar, as it is previously known to occur only in the coastal area of Sambirano (Glaw and Vences 2007). About 20 % of reptile taxa found in Mandrozo (seven of 36 species) are CITES Appendix II species (*Brookesia brygooi, Furcifer lateralis, F. oustaleti, Uroplatus guentheri, Phelsuma madagascariensis, P. mutabilis, P. klemmeri*) and, if commercial collecting takes place, this activity may affect the survivorship of these reptile populations. Moreover, most of Malagasy reptile species have not been evaluated (NE: Not Evaluated) on the IUCN Red List. This is one of the major issues in reptile conservation in Madagascar and, in the future, if all species are assessed, the importance of Bemanevika and Mandrozo for biodiversity conservation might likely increase.

Birds: Recently, the importance of Manambolomaty, Mandrozo, and Bemanevika sites in maintaining threatened avifauna diversity has been highlighted (Razafimanjato et al. 2007, Rene de Roland et al. 2007, BirdLife International 2008, Rabearivony et al. 2008, Rabenandrasana et al. 2009), and national protection of these sites may conserve at least 104 endemic forest birds and waterbirds of which 20 species are threatened (Table 2 and Supplementary Material). Of the 11 threatened taxa documented at the three sites seven are found only at Bemanevika (Madagascar pochard *Aythya innotata* (CR), Meller's duck *Anas melleri* (EN), Madagascar serpent-eagle *Eutriorchis astur* (EN), Madagascar red owl *Tyto soumagnei* (VU), Madagascar harrier *Circus macrosceles* (VU), Bernier's Vanga *Oriolia bernieri* (VU) and Madagascar rail *Rallus madagascariensis* (VU)), three at Manambolomaty (Madagascar fish eagle *Haliaeetus vociferoides* (CR), Madagascar teal *Anas bernieri* (EN) and Madagascar Plover *Charadrius thoracicus* (VU)) and two at Mandrozo (Madagascar fish eagle *Haliaeetus vociferoides* (CR) and Sakalava rail *Amaurornis olivieri* (EN)). All threatened waterbirds at these sites have declining populations attributed to human activities such as hunting, degradation of wetland habitat by conversion to rice paddies, and burning and collecting of wetland plants such as Phragmites and *Cyperus* species (Rene de Roland et al. 2007, BirdLife International 2008, Rabenandrasana et al. 2009). In addition, as a consequence of deforestation, wetlands have become shallower from siltation and have driven the loss of suitable habitat for most of the critical endangered waterbirds (BirdLife International 2008). Until recently, for instance, the Madagascar pochard was classified as a species 'possibly extinct' in the world (BirdLife International 2004, Butchart et al. 2006). The presence of the Sakalava rail at Mandrozo is noteworthy as it might be 'locally extinct' in some areas where it was previously recorded, e.g., at Lake Bemamba and Nosy Ambositra marsh (Rabenandrasana et al. 2009). Among the least known of the country's waterfowl, the

Madagascar teal was rediscovered in 1969 when small numbers were found in Bemamba and Masama Lakes south of Antsalova (Salvan 1970, Andriamampianina 1976, Young et al. 2003). In 1973, 140 individuals were recorded at these lakes (Scott and Lubbock 1974) and, currently, its population is fragmented from Loky Bay in the north to Tsimanampetsotsa Lake in the south (Young et al. 2003). The only presences reported for this species have been at Lake Antsamaka, at the Manambolomaty RAMSAR site, and in the estuaries of the Betsiboka and Tsiribihina Rivers (Thorstrom and Rabarisoa 1995, Young et al. 2003). The inclusion of the three important host sites such as Bemanevika, Mandrozo and Manambolomaty into Madagascar's protected area network may help to slow down the declining population trend of these threatened waterbird species listed above.

The Madagascar serpent-eagle (EN) is a forest-dependent species that is known mainly from the primary eastern rain forests of Madagascar (Thorstrom et al. 2003, Thorstrom and Rene de Roland 2003ab). The Madagascar serpent-eagle was once regarded as one of the rarest birds of prey in the world owing to the loss of the primary forest cover (Collar et al. 1994), but due to the work of The Peregrine Fund it is now well known throughout many eastern rainforest blocks (Thorstrom and Rene de Roland 2003b). Also, the Madagascar serpent-eagle is a secretive species with a low productivity and this may also contribute to its rarity in Madagascar (Thorstrom and Rene de Roland 2003b). Another threatened raptor species, the Madagascar harrier (VU) is dependent on marsh, grassland and wooded grassland habitats for its survival (Thorstrom et al. 2003). It has an extremely broad distribution in Madagascar, but three major threats were recently identified to reducing its suitable habitat: Local consumption of eggs, nestlings and adults as food source for protein; burning of grasslands to stimulate fodder for cattle and land clearing; and the conversion of low-altitude marshes and wetlands into rice fields for human food production (Rene de Roland et al. 2004). However, apart from the raptor species mentioned, many other threatened forest birds may also benefit from the protection of these three sites. For example, the Bernier's vanga (VU) was reported to occur from sea level to 1,000 m (Langrand 1990, Thorstrom and Rene de Roland 2001), but was found in Bemanevika at 1,600 m (L.-A. Rene de Roland, pers. obs.). It has a limited distribution in eastern rainforests and appears to be relatively rare throughout its range in northern Madagascar (Langrand 1990, Evans et al. 1992, Thompson and Evans 1992).

Small mammals: At the Bemanevika site 92 % (23 of 25 species) of the small mammals recorded are endemic (Supplementary Material). The only two introduced species confirmed at this site were those widely spread throughout Madagascar, the Black rat *Rattus rattus* and Asian house shrew *Suncus murinus* (Goodman et al. 2003). Historically, these two species were introduced by the earliest humans migrating to Madagascar's coastal areas (Duplantier and Duchemin 2003). In Bemanevika, we found the Hairy-tailed tree rat *Brachytarsomys villosa* (EN), which was elevated to species status 20 years ago (Carleton and Schmidt 1990). The Hairy-tailed tree rat *B. villosa* had never been found in the wild until a recent survey by Goodman et al. (2001) at Anjanaharibe-Sud Special Reserve.

Lemurs: All of the 71 species and sub-species of lemurs are endemic to Madagascar (Mittermeieret al. 2006). A total of 17 taxa were recorded for the Bemanevika (8 species) and Manambolomaty (10 species) sites, with the Aye-aye (*Daubentonia madagascariensis*) being encountered on both. Although the Aye-aye has been found in many new localities and in many different parts of Madagascar, this nocturnal lemur does not appear to be abundant anywhere. Its numbers are believed to be declining with the loss of forest habitat (Sterling 1994, Mittermeier et al. 2006), and it is currently classified as Data Deficient according to IUCN (2008). Many records for this species are based only on interviews with local people or research guides (e.g., Randrianambinina et al. 2003, Olivieri et al. 2006, Randrianambinina and Rasoloharijaona 2006). In 2005, one individual was found in a fig tree *Ficus* sp. growing in the middle of a banana plantations along the Manambolomaty seasonal river (J. Rabearivony and L.-A. Rene de Roland, pers. obs.), and in 2006, another individual was observed on the forest edge of Soamalipo Lake (L.-A. Rene de Roland, pers. obs.). A live animal was captured at Bemanevika site in 2000 by a villager in Amberivery, about 15 km south of this site; scraping signs by this species were also observed on a dead tree in 2008 (Lhota et al. 2008, The Peregrine Fund 2008b). Except for the Aye-aye and Western avahi *Avahi occidentalis*, all of the lemur species recorded at the Manambolomaty site during biodiversity inventories had also been confirmed by Ausilio and Raveloarinoro (1998). Lemur taxonomy is still in the process of revision due to a surge in discoveries and additional information on distributions (Ganzhorn et al. 2006), which could add up to the lemur diversity at both the Manambolomaty western deciduous forest and the Bemanevika transitional rainforest sites (Supplementary Material). Four threatened species were recorded during these inventories: Western avahi *Avahi occidentalis* (EN), Grey bamboo lemur *Hapalemur griseus* (VU), Milne-Edward's sportive lemur *Lepilemur edwardsi* (VU) and Western grey bamboo lemur *H. occidentalis* (VU) most likely experiencing similar conservation threats. These threats are habitat loss or destruction through burning to create new pasture for livestock or for practicing hill rice cultivation, charcoal production and mining (Mittermeier et al. 2006). Repeated burning of forests can result in extirpation of some lemur species like the Coquerel's sifaka *Propithecus coquereli* at the Bora Special Reserve (Koenig and Zavasoa 2006). Throughout Madagascar, and in many villages, Grey bamboo lemurs *H. griseus* (VU) are also frequently kept as pets. Furthermore, all four threatened species including many other threatened lemur taxa, are hunted unsustainably (Garcia and Goodman 2003, Patel et al. 2005, Mittermeier et al. 2006). Impacts of human activities might be much more severe to species with narrow geographical distributions such as Western avahi *Avahi occidentalis* (EN). Currently, only one legally protected area Ankarafantsika National Park, hosts a high density (estimated at 67 individuals / km^2) of this species (Ganzhorn 1988), and a protected area network extension under SAPM may help to protect this and other lemur species from local extinction too (Mittermeier et al. 2006).

LONG-TERM CONSERVATION OF THE SITES. Protection of a flagship species is very important in conservation as it helps to protect many other threatened species, biodiversity and ecosystems (Landres et al. 1988, Favreau et al. 2006). This has previously been demonstrated in the Manambolomaty site by using the critically-endangered Madagascar fish eagle as a flagship species (Rabearivony et al. 2008).

Thus, conservation efforts to protect the Madagascar fish eagle at Manambolomaty can benefit other threatened taxa like for examples the Western avahi *Avahi occidentalis* (EN*),* Grey bamboo lemur *Hapalemur griseus* (VU) and Milne-Edward's sportive lemur *Lepilemur edwardsi* (VU)), bats (e.g. Flying fox *Pteropus rufus* (VU), birds (e.g., Madagascar heron *Ardea humbloti* (EN), Madagascar sacred ibis *Threskiornis bernieri* (EN), Madagascar little grebe *Tachybaptus pelzelnii* (VU) and Madagascar plover *Charadrius thoracicus* (VU), and reptiles, e.g., Madagascar big-headed turtle *Erymnochelys madagascariensis* (EN). During the 8-years (2002-2009) of community-based wetlands and Madagascar fish eagle conservation in Manambolomaty, the population of Madagascar fish eagle has remained stable at 27-32 individuals (Table 3).

The two local Associations in Manambolomaty FIZAMI (*FIkambanana Zanatany Andranobe MIray*) and FIFAMA (*FIkambanana FAmpandrosoana Mamokatra Ankerika*) have demonstrated their ability to ensure the ecological viability of this site in managing their natural resources as a sustainable source of revenue (Rabearivony et al. 2008). Currently, we are duplicating the same community-based wetland conservation strategies around Mandrozo Lake, which have been achieved at the Manambolomaty site. Recent monitoring revealed 5-6 pairs of Madagascar fish eagle at this site (Table 3). With an increased commitment from local and regional authorities i.e. the *Tompondrano* (lake keeper) and stakeholders, the three local Associations FIVOMA (*FIkambanana VOnjisoa MAndrozo*), FIMITOVE (*FIkambanana MIaro TOntolo iainana VEromanga*) and ZAMAMI (*ZAnatany MAndrozo MItambatra*) in charge of the wetlands management are currently operating well. Thus, like in the Manambolomaty site, many threatened taxa will also receive the benefit from the protection of the critically endangered Madagascar fish eagle (see Supplementary Material for exhaustive list).

In Bemanevika, the Madagascar pochard occupies the same lakes as the Meller's duck *Anas melleri* (EN) and Red-billed teal *Anas erythrorhyncha* (LC). Currently, the minimum size of a viable population is unknown for the Madagascar pochard with 100 % of the global population being at this site only. The survival of the remaining 18-20 individuals in Bemanevika is of great concern, as it is one of the most endangered bird species in the world (BirdLife International 2004, Butchart et al. 2006). Presently, a captive breeding program is in progress to conserve this critically-endangered species. However, because local people are very sensitive of foreigners (including all nongovernmental organisations working on bird conservation), they believe the foreigners may steal, sell and export this rare duck, and this local attitude has lead to a conservation and captive breeding program '*in situ*' to maintain local social stability. Since conservation should focus mainly on the management of all human-induced pressures and activities (e.g., hunting, transformation of lakes to rice fields), the local stakeholders in Bemanevika are represented by two associations FBM (*Fikambanana Bemanevika Miraihina*) and FIMAKA (*FIkambanana Miaro ny Ala Ketsany Amberivery*) and they are supporting the Madagascar pochard conservation program and have shown their active involvement in the protected area creation process of this site.

CONCLUSION

The three proposed sites Manambolomaty, Mandrozo, and Bemanevika, support several endemic and highly threatened vertebrate taxa of fish, herpetofauna, birds, small mammals and primates. The population stability of the two flagship species, the Madagascar fish eagle in Manambolomaty and Mandrozo and the Madagascar pochard in Bemanevika, indicates that these three sites are ecologically stable. The hotspot approach based on the endemism rate and IUCN species Redlist supports the justification of protecting these three important wetland sites. However, it is emphasized that biodiversity protection works better if it is coupled with local resource management and socio-economic consideration (see Rabearivony et al. 2008).

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APPENDIX 1. VOUCHER SPECIMENS FROM BEMANEVIKA.

Reptiles: *Brookesia therezieni* (UADBA 42578, 42579 and 42580), *Calumma hafahafa* (UADBA 42582, 42583 and 42584), *Calumma crypticum* (UADBA 42585 and 42586), *Calumma boettgerie* (UADBA 42600), *Uroplatus ebenaui* (UADBA 42587), *Zonosaurus madagascariensis* (UADBA 42588), *Trachylepis gravenhorstii* (UADBA 42589, 42590), *Lygodactylus guibei* (UADBA 42592), *Madascincus mouroundavae* (UADBA 42591, 42593, 42594 and 42595), *Madascinus intermedius* (UADBA 42596, 42597, 42598 and 42599).

Amphibians: *Heterixalus andrakata* (UADBA 42601 and 42602), *Aglyptodactylus madagascariensis* (UADBA 42613, 42614, 42615, 42616 and 42617), *Boophis axelmeyeri* (UADBA 42646), *Boophis cf. brachychir* (UADBA 42653 and 42654), *Boophis cf. madagascariensis* (UADBA 42643 and 42644), *Boophis marojezensis* (UADBA 42655, 42656, 42657 and 42658), *Boophis vittatus* (UADBA 42659 and 42660), *Boophis cf. vittatus* (UADBA 42662), *Blommersia blommersae* (UADBA 42619 and 42620), *Blommersia* sp. (UADBA 42621 and 42622), *Gephyromantis ambohitra* (UADBA 42633, 42634, 42635, 42636, 42637, 42638, 42639 and 42640), *Gephyromantis cf. ambohitra* (UADBA 42632), *Mantella pulchra* (UADBA 42618), *Mantidactylus femoralis* (UADBA 42626), *Mantidactylus guttulatus* (UADBA 42628 and 42629), *Mantidactylus mocquardi* (UADBA 42627), *Mantidactylus opiparis* (UADBA 42630), *Spinomantis peraccae* (UADBA 42642), *Plethodontohyla* sp. (UADBA 42605, 42606, 42607, 42608, 42609 and 62645), *Rhombophryne alluaudi* (UADBA 42603 and 42604), *Scaphiophryne boribory* (UADBA 42610 and 42611), and *Ptychadena mascareniensis* (UADBA 42612).

SUPPLEMENTARY MATERIAL.

AVAILABLE ONLINE ONLY:

List of species recorded at the three SAPM sites, endemism and IUCN status (1=species present but not recorded during this study; 2=species present and found by local community; *=recorded species) (IUCN categories: DD=data deficient, LC=least concern, VU=vulnerable, NT=near threatened, EN=endangered, CR=critically endangered).

Les oiseaux de l'archipel de Nosy Hara, au nord nord-ouest de Madagascar et la nouvelle distribution connue du Gobe mouche de Ward (*Pseudobias wardi*)

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RÉSUMÉ

Peu d'informations ornithologiques étaient disponibles sur l'archipel de Nosy Hara, au nord nord-ouest de Madagascar. Afin de constituer une base de données scientifique, nous avons entrepris un inventaire du peuplement aviaire de cet archipel entre fin septembre et début octobre 2005. Pour la collecte des données, deux méthodes complémentaires ont été utilisées sur l'île de Nosy Hara, à savoir le taux de rencontre et les observations générales mais la présence des espèces dans certains îlots de l'archipel a été notée par la deuxième de ces techniques. Un total de 31 espèces d'oiseaux a été rencontré au cours de cet inventaire. Outre les espèces inféodées au milieu marin et celles des zones littorales, 18 espèces terrestres ont été trouvées sur l'île et une sur l'île d'Andalatsara. Bien que l'archipel présente un appauvrissement en espèces d'oiseaux par rapport aux autres écosystèmes forestiers de la grande terre, son importance ornithologique n'est pas à négliger. Le Gobe mouche de Ward *Pseudobias wardi* a été découvert au cours de cet inventaire dans un type d'habitat duquel il n'était pas encore connu et dans une nouvelle localité qui étend sensiblement sa distribution connue. La préservation de cet archipel est justifiée pour préserver ses richesses biologiques face aux diverses pressions anthropiques.

ABSTRACT

The Nosy Hara archipelago, located in the north north-western tip of Madagascar is made up of about 12 small islands surrounded by coral reef. Limestone formations of the Eocene called '*Tsingy*' are their main substrate on which develops a narrow surface of western dry forest. With its aesthetic landscape, economic and socio-cultural and its natural resources, this archipelago forms the jewel of this part of the island. However, scientific information on biodiversity and ecology, especially on the birds of this archipelago were not available. To fill this gap, an inventory of birds was conducted between late September and early October 2005. For data collection, two complementary methods were used on the island of Nosy Hara, namely timed transects and general observations. However, the presence of species in some islands of the archipelago has been noted by the second technique. A total of 31 bird species was encountered during the inventory. Apart the marine and coastal bird species, 18 terrestrial species were found on the Nosy Hara and one on Andalatsara island. Seven species are endemics of which two are aquatics and five terrestrials. These results show that bird diversity of the inventory area is relatively poor showing the classic features of island fauna. However, a new type of habitat in a new locality for *Pseudobias wardi* was discovered during the inventory which extends the known distribution to date of this species in the western dry forests of Madagascar. Moreover, the beaches of some surrounding islands are an ideal place for nesting of some species of *Sterna* spp. Similarly, the cliffs provide nesting, hunting or resting sites for some birds of prey such as *Haliaeetus vociferoides* which is a critically endangered species. The preservation of this archipelago is then biologically essential face to various anthropogenic pressures.

MOTS CLEFS : oiseaux, *Pseudobias wardi*, distribution, archipel de Nosy Hara, Madagascar.
KEYWORDS: Bird community, *Pseudobias wardi*, distribution, Nosy Hara archipelago.

INTRODUCTION

De nombreuses études ont été consacrées aux oiseaux de Madagascar et cela dans différents types d'écosystèmes. Grâce aux travaux de plusieurs chercheurs, le peuplement aviaire de ces écosystèmes et la distribution de chaque espèce sur l'île sont apparemment bien connues (Rand 1936, Griveaud 1967, Dorst 1972, Wilmé 1996, Goodman et al. 2000, Goodman et al. 1997, Hawkins et Goodman 1999, Raherilalao et al. 2002, Raherilalao et Wilmé 2008) de sorte que les recherches récentes s'orientent davantage vers les analyses de la distribution ou les modèles d'endémisme (Raherilalao et Goodman 2003, Raherilalao et Wilmé 2008). Rappelons aussi que la plupart des études ont été axées sur la Grande île en négligeant en quelque sorte les petites îles et les îlots satellite pour lesquels les informations sur la biodiversité, dont celles portant sur les oiseaux, restaient assez vagues. Il est pourtant bien connu ailleurs que les communautés insulaires présentent des caractéristiques différentes de celles des grandes terres limitrophes. Les particularités insulaires sont ainsi d'autant plus prononcées que l'île est petite, distante du continent ou de la grande terre et isolée depuis longtemps, autant

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de facteurs qui affectent les taux de colonisation, d'extinction et le degré de spéciation (MacArthur et Wilson 1967).

Pour combler en partie cette lacune, un inventaire ornithologique a été réalisé entre la fin du mois de septembre et le début du mois d'octobre 2005 sur l'archipel de Nosy Hara qui est situé à l'extrême nord-ouest de Madagascar, entre le cap Vahilava au Nord et le cap Anorontany au Sud (Figure 1).

Parmi les îles et archipels de la partie nord-ouest de Madagascar, Nosy Hara constitue un joyau de par sa richesse exceptionnelle et plus particulièrement ses aspects éco-biologiques, économiques et culturels. Cependant, et bien que la gestion des ressources doive être fondée sur la connaissance de la biodiversité, l'archipel était peu connue d'un point de vue scientifique, y compris en ce qui concerne les oiseaux, les données existantes étant fragmentaires et difficile d'accès. Les rares informations dont nous disposions sur les oiseaux de cet archipel et de ses environs avant cette étude trouvaient leur origine dans les résultats de deux expéditions, l'une par Zicoma (1999) et l'autre par Metcalf et ses collaborateurs (2001). Suite aux travaux d'inventaires ornithologiques dans la région, l'équipe du projet Zicoma (1999) a proposé Nosy Fasy, Nosy Faty et Nosy Foty comme sites d'observation pour les sternes (*Sterna caspia*, *S. bergii*, *S. dougalii*, *S. fuscata* et *S. benghalensis*) et les noddis (*Anoüs tenuirostris* et *A. stolidus*) en considérant les îlots coralliens extérieurs à titre de « sites d'espèces grégaires » suivant les critères de la convention de RAMSAR (convention sur les zones humides d'importance internationale) pour *Sterna benghalensis, S. bergii* et *S. dougallii*. En 2001, Metcalf et al. ont trouvé une vingtaine d'espèces d'oiseaux sur l'ensemble de Nosy Hara, Nosy Lakandava, Nosy Anjombavola et Nosy Andatsara et 25 espèces sur Nosy Vaha et Nosy Hao, sachant que 19 espèces d'oiseaux n'ont été observées qu'à Nosy Hara. Parmi ces espèces, quatre n'ont pas été recensées au cours de notre inventaire, à savoir *Apus melba*, *Charadrius pecuarius*, *Corythornis vintsioides* et *Numenius phaeopus*.

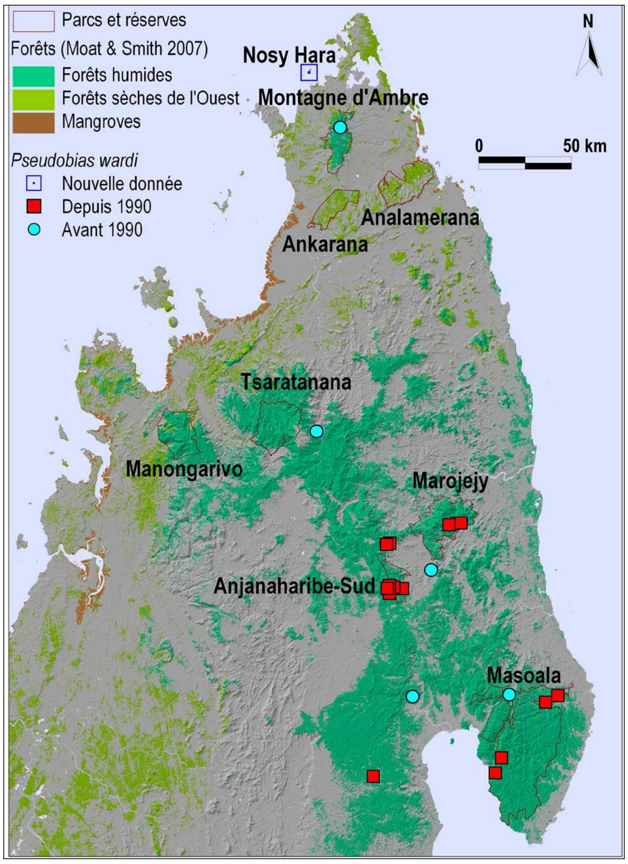

FIGURE 1. Carte montrant les différentes localités dans la partie septentrionale de Madagascar où la présence de *Pseudobias wardi* a été notée.

Nous nous proposons dans cet article d'apporter des informations supplémentaires sur l'avifaune de Nosy Hara et ses environs tout en précisant ses particularités afin de renforcer la connaissance scientifique relative à la diversité écologique et biologique de ce site ainsi que sa pertinence pour la conservation en soulignant aussi l'importance de poursuivre sa documentation et plus particulièrement les études de suivi des mouvements saisonniers des oiseaux entre la grande terre et les îlots de l'archipel. Ces informations pourront constituer un outil de base pour les programmes de recherche, de conservation et de développement écotouristique de la région.

MÉTHODES

DESCRIPTION DU SITE. L'archipel est constitué par de nombreux îlots et des petites îles dont la plus grande est celle de Nosy Hara. Notre campement, surnommé « Campement *Sandôzy* » par les habitants de la région, était implanté sur l'île à 10,5 km à l'ouest du village d'Ampasindava, sur le territoire de la commune rurale de Mangoaka, région de Diana, aux coordonnées E49° 00,5' et S12° 14,9'.

De forme allongée, l'île de Nosy Hara mesure deux à trois kilomètres du nord au sud, avec une largeur de quelques dizaines de mètres et elle occupe une superficie de 312 ha. Elle est constituée dans son ensemble de calcaire fortement érodé, donnant lieu à une formation connue à Madagascar sous le terme de *tsingy*, désintégrée par endroit ou formant des blocs empilés de différentes tailles. Les calcaires dolomitiques compacts et les *tsingy* de l'Eocène sont très découpés et forment par endroit de profonds canyons de forme et d'étendue variées qui sont bordés par des falaises abruptes et surélevées (Besairie 1972). Aucune véritable grotte n'est cependant connue de cet ensemble et le site ne présente d'ailleurs aucun réseau hydrographique exposé ou souterrain. Les quelques dolines observées à la surface de ces formations calcaires ne laissent aucune trace d'emmagasinage d'eau par temps sec, comme c'est par exemple le cas sur le plateau calcaire Mahafaly dans le sud-ouest malgache.

Les quelques blocs forestiers de l'île sont définis comme étant une formation sèche de l'ouest selon Moat et Smith (2007), d'une hauteur variable suivant le relief et la nature du substrat. Sur le flanc et dans certaines parties du fond du canyon se développe une formation végétale assez dense avec des formes ligneuses à feuilles caduques poussant sur un sol assez mince mais riche en matière organique ; la canopée y est généralement ouverte. Les arbres d'une hauteur comprise entre 5 et 8 m avec des émergeants variant de 10 à 12 m environ sont dominés par les ficus (*Ficus* spp. Moraceae) et les légumineuses tels que le tamarinier (*Tamarindus indica* Fabaceae) et les palissandres (*Dalbergia* spp. Fabaceae). Le sous-bois est bien fourni ; les arbustes, les petites lianes et les plantes épineuses sont nombreuses et forment souvent une barrière impénétrable de par l'enchevêtrement de leurs branches. Sur le plateau calcaire ainsi que dans la dépression en forme de cuvette qui occupe la surface de certaine partie de la formation de *tsingy* s'installe une végétation particulière avec une hauteur variant de 2 à 3 m, dans laquelle on retrouve des aloès (*Aloe* spp. Liliaceae) et des euphorbes (*Euphorbia* spp. Euphorbiaceae) associées à d'autres plantes succulentes. L'abondance de ces plantes xérophytiques dans certains endroits donne un aspect caractéristique à l'ensemble de ce paysage écologique. Dispersés dans cet ensemble floristique, des arbres nains en forme de bouteille, représentés principalement par *Delonyx* sp. (Fabaceae) et *Pachypodium* sp. (Apocynaceae) et quelques baobabs (*Adansonia* sp. Malvaceae) s'accordent harmonieusement avec le milieu. D'autres types de formations végétales sont également rencontrés dans certains endroits, comme une mangrove dans le bas-fond mais d'une surface extrêmement réduite en étant directement ouverte sur la mer et souvent inondée à marée haute. L'ensemble de la végétation forme ainsi une mosaïque qui souligne la nature et la topographie du milieu.

Le bioclimat relève de l'étage sec, sous-étage 2 du type S2b qui est donc caractérisé par une température moyenne des mois les plus froids comprise entre 16 °C et 18 °C avec une saison sèche qui dure neuf mois (Cornet 1972). Par sa position géographique, la mousson influence considérablement le climat de la région (Donque 1975). Elle apporte des vents assez violents, une forte humidité et des averses. Le climat présente deux saisons bien distinctes, avec l'hiver qui est plus sec et qui s'étend du mois d'avril au mois d'octobre et l'été plus chaud et plus humide du mois de novembre au mois de mars. Les données météorologiques enregistrées au cours de cet inventaire biologique qui s'est déroulé du 28 septembre au 6 octobre 2005 ont permis d'enregistrer un temps toujours chaud avec une moyenne des températures minimales de 25 °C, une moyenne des températures maximales de 30,5 °C et aucune précipitation.

COLLECTE DE DONNÉES. Afin d'inventorier l'avifaune du site, deux méthodes complémentaires ont été utilisées, à savoir le taux de rencontre et les observations générales (Bibby et al. 1992).

La méthode « Taux de rencontre » est une technique semi-quantitative qui consiste à marcher lentement avec une vitesse constante (environ 0,5 km par heure) le long d'un transect de 1 km pré-établi le long d'une piste et à noter tous les contacts visuels et auditifs de chaque individu d'oiseau pendant un intervalle de temps défini de 1 heure. Le taux de rencontre s'exprime par le nombre de fois où l'espèce est rencontrée par unité de temps (ici une heure). Un seul transect traversant les différents microhabitats accessibles ayant pu être établi sur Nosy Hara, cette méthode a rapidement trouvé ses limites et plus particulièrement sur les autres îles de l'archipel.

Les observations générales consistent à marcher le long des sentiers, sur des itinéraires non standardisés et à noter tous les oiseaux vus ou entendus. Comme la plupart des oiseaux ont des rythmes d'activité concentrée sur les matinées, des recherches actives ont été généralement conduites tous les jours entre 0530h et 1030h mais toutes les autres observations ont également été consignées. Ces données ont été utilisées pour pouvoir documenter la présence des espèces qui n'auraient pas été trouvées au cours du recensement standardisé. Elles constituent ainsi des données qualitatives qui complèteront les données obtenues à partir du taux de rencontre.

Les autres îlots visités (Andantsara, Nosy Mely, Belomotsa et Lakandava) n'ont pu être inventoriés systématiquement pour des raisons techniques. En outre, Anjombavola étant une île sacrée, elle n'a pas pu être prospectée, de sorte que les quelques données qui concernent ces différents îlots proviennent uniquement d'observations aléatoires réalisées à des heures différentes et parfois même à une certaine distance.

La taxinomie et les noms scientifiques sont conformes à ceux utilisés par Goodman et Hawkins (2008).

RÉSULTATS

Bien que de surface réduite et dotée de conditions écologiques peu favorables, l'île de Nosy Hara abrite une avifaune relativement importante avec 31 espèces. Dix-huit d'entre elles sont des espèces des milieux forestiers et des milieux ouverts, et *Tyto alba* n'a été observé que sur l'île d'Andalatsara (Tableau 1). Les 13 autres espèces sont inféodées au milieu marin ou fréquentent habituellement les zones littorales, et une seule espèce des zones humides est endémique de Madagascar, *Ardea humbloti*.

Parmi les espèces forestières et des milieux ouverts, 14 espèces ont une aire de distribution limitée dont cinq espèces endémiques de Madagascar et neuf endémiques de la région, c'est à dire de Madagascar et des îles voisines (Comores, Seychelles, Mascareignes). Les espèces appartenant aux taxons endémiques supérieurs (famille, sous-famille) sont représentées sur l'île par *Calicalicus madagascariensis* et *Pseudobias wardi* de la famille endémique de Madagascar et des Comores, celle des Vangidae. La découverte de cette dernière espèce sur Nosy Hara constitue la donnée la plus intéressante de cet inventaire car le Gobe mouche de Ward n'était connu jusqu'alors que des forêts humides et n'avait jamais été recensé dans des formations sèches du versant occidental.

La plupart des espèces ont été rencontrées quotidiennement, comme par exemple *Treron australis*, *Centropus toulou*, *Hypsipetes madagascariensis*, *Terpsiphone mutata* et *Nectarinia souimanga*. Peu n'ont été observées que rarement comme ce fut le cas de *Calicalicus madagascariensis* ou *Turnix nigricollis,* cette dernière étant la seule espèce à mœurs terrestres que nous avons relevée. Les espèces de sous-bois, c'est à dire celles qui utilisent généralement les parties inférieures de la strate verticale, semblaient peu fréquentes, et n'étaient représentées que par *Streptopelia picturata* et *Centropus toulou*.

Cinq espèces dominent les populations d'oiseaux des milieux forestiers et ouverts de l'île avec des populations relativement importantes par rapport à la superficie assez réduite du site. Il s'agit de *Treron australis*, *Centropus toulou, Hypsipetes madagascariensis*, *Terpsiphone mutata* et *Nectarinia souimanga*. Les autres espèces ont des populations faiblement représentées comme *Turnix nigricollis* et *Neomixis striatigula* qui n'ont été relevées que par l'observation d'un seul individu pendant toute la durée de l'inventaire (Tableau 1).

Au cours de nos observations journalières autour de l'île, plusieurs espèces d'oiseaux ont été observées en vol au-dessus de la mer ou du rivage, comme *Phaethon lepturus*, *Sterna dougallii*, *S. bergii*, *Anoüs stolidus* et *A. tenuirostris*. Nous avons également relevé la présence de groupes importants d'un limicole, *Arenaria interpres*, qui a été régulièrement observé sur les plages de certains îlots calcaires au voisinage immédiat de Nosy Hara. Nosy Famaho est de toute évidence un site ornithologique important car il abrite sur une superficie réduite un peuplement avien bien structuré dans l'espace. Une colonie importante de sternes, appelées communément *Samby* dans

TABLEAU 1. Liste des espèces d'oiseaux trouvées sur les îlots de Nosy Hara et ses environs. Le signe * indique les espèces endémiques de Madagascar, (*) : les espèces endémiques de la région, A : aquatique, M : marin et NA : non aquatique ou terrestre. Les chiffres indiquent le nombre maximum de rencontres (visuelle et auditive) pour chaque espèce pendant cinq comptages durant cinq jours consécutifs par la méthode de taux de rencontre.

Taxons	Noms vernaculaires français	Milieu	Abondance relative
Phaethontidae			
Phaethon lepturus	Phaéton à queue blanche	M	
Ardeidae			
Nycticorax nycticorax	Héron Bihoreau à calotte noire	A	
Egretta dimorpha	Aigrette dimorphe	A	
Ardea cinerea	Héron cendré	A	
* *Ardea humbloti*	Héron de Humblot	A	
Accipitridae			
* *Haliaeetus vociferoides*	Pygargue de Madagascar	NA	
Falconidae			
(*) *Falco newtoni*	Faucon de Newton	NA	1
Turnicidae			
* *Turnix nigricollis*	Turnix de Madagascar	NA	1
Rallidae			
(*) *Dryolimnas cuvieri*	Râle de Cuvier	A	1
Scolopacidae			
Arenaria interpres	Tournepierre à collier	M	
Sternidae			
Sterna dougallii	Sterne de Dougall	M	
Sterna fuscata	Sterne fuligineuse	M	
Sterna bergii	Sterne huppée	M	
Sterna benghalensis	Sterne voyageuse	M	
Anoüs stolidus	Noddi brun	M	
Anoüs tenuirostris	Noddi à bec grèle	M	
Columbidae			
(*) *Streptopelia picturata*	Tourterelle peinte	NA	2
(*) *Treron australis*	Pigeon vert de Madagascar	NA	12
Cuculidae			
(*) *Centropus toulou*	Coucal malgache	NA	5
Tytonidae			
Tyto alba	Chouette effraie	NA	
Caprimulgidae			
(*) Caprimulgus madagascariensis	Engoulevent de Madagascar	NA	
Apodidae			
Apus balstoni	Martinet noir africain	NA	
Pycnonotidae			
Hypsipetes madagascariensis	Bulbul noir	NA	14
Sylviidae			
* *Neomixis striatigula*	Grande Eroesse	NA	1
Monarchidae			
(*) *Terpsiphone mutata*	Gobe-mouche de Madagascar	NA	8
Nectariniidae			
(*) *Nectarinia souimanga*	Souimanga malgache	NA	9
(*) *Nectarinia notata*	Souimanga angaladian	NA	2
Vangidae			
* *Calicalicus madagascariensis*	Vanga à queue rousse	NA	2
* *Pseudobias wardi*	Gobe-mouche de Ward	NA	2
Dicruridae			
(*) *Dicrurus forficatus*	Drongo malgache	NA	2
Corvidae			
Corvus albus	Corbeau pie	NA	

la région, formée au moins de quatre espèces (*Sterna dougallii, S. fuscata*, *S. bergii et S. benghalensis*) et composée de plusieurs individus à différents ages (adultes, subadultes, juvéniles et oisillons) se cantonnent sur le banc de sable d'une vingtaine de mètres environ dans sa partie orientale et qui sert de site de reproduction pour ces oiseaux. Hormis les sternes, d'autres espèces des zones littorales fréquentent la partie occidentale plus rocailleuse et à végétation basse dont *Nycticorax nycticorax*, *Ardea cinerea* et *Arenaria interpres*.

DISCUSSION

Comme la plupart des îles malgaches, celles de l'archipel de Nosy Hara hébergent une faune ornithologique assez importante. Mais l'observation la plus remarquable a été celle d'une espèce assez commune dans les forêts humides peu perturbées mais qui n'avait encore jamais été observée dans le biome sec de l'ouest. Sur la pointe sud de l'île où s'installe une forêt sèche, nous avons pu observer à maintes reprises au cours des observations matinales au moins deux individus de *Pseudobias wardi,* le plus souvent perchés dans un arbre. Par sa taille similaire à celle de *Calicalicus madagascariensis*, une autre espèce de Vangidae, par la coloration blanche et bleu nuit de son plumage et surtout par ses vocalisations caractéristiques, cette espèce est facilement identifiable. De par son code de couleur, on pourrait, à la rigueur, la confondre avec des jeunes mâles de *Terpsiphone mutata* en phase blanche, mais elle en diffère par quelques caractéristiques bien visibles, comme le cou blanc et la poitrine noire, alors que chez *T. mutata*, le cou et la nuque sont entièrement noirs et la poitrine blanche. En outre, *P. wardi* ne possède pas les deux rectrices centrales très allongées de *T. mutata*.

Au cours de leurs investigations dans la région de Nosy Hara et ses environs (Nosy Fasy, Nosy Faty, Nosy Foty, Nosy Vaha et Nosy Hao), Zicoma (1999) et Metcalf et al. (2001) n'ont rapporté aucune mention de *Pseudobias wardi*. La distribution connue englobait les forêts humides depuis le Parc National (PN) d'Andohahela (Hawkins et Goodman 1999) dans le sud-est jusqu'au PN de Marojejy (Goodman et al. 2000, Raherilalao et Goodman, 2003) et les forêts sub-humides du nord-ouest en incluant la Réserve Naturelle Intégrale du Tsaratanana (Albignac 1970, Zicoma 1999). Rand (1936) remarquait qu'elle n'était trouvée que dans la forêt humide orientale. Elle est largement distribuée dans son aire de répartition ; cependant, comme le montrent les observations faites dans plusieurs forêts humides malgaches, sa densité relative est généralement très faible (Raherilalao non publié). Sa présence avait été notée dans quelques forêts se trouvant à peu de distance de Nosy Hara, notamment le PN de la Montagne d'Ambre où la seule mention qui existe est un nid récolté par le Dr Sicard en 1921 et conservé au Musée Zoologique de Strasbourg (Koenig 1993). Toutefois, plus d'un demi siècle après la découverte de ce nid, bien que Goodman et ses collaborateurs (1996) aient réalisé un inventaire biologique le long d'un transect altitudinal dans trois sites distribués entre 340 et 1350 m d'altitude, aucun signe de *P. wardi* n'a été rapporté dans ce parc. Les données portant sur les forêts humides du massif du Tsaratanana sont éparses incluant les trois individus récoltés par Renaud Paulian le 15 octobre 1949 à 1700 m d'altitude et déposés au Parc Botanique et Zoologique d'Antananarivo (PBZT), les informations recueillies par Albignac (1970) et celles de Zicoma (1999). Ce dernier a réalisé une prospection dans un site portant les caractéristiques géographiques suivantes : E48° 44' à E49° 01', S13° 51' à S14° 12', 227 à 876 m d'altitude. Les travaux d'inventaires intensifs menés suivant deux transects altitudinaux englobant plusieurs sites distribués entre 400 et 1869 m d'altitude dans la Réserve Spéciale (RS) de Manongarivo n'ont révélé aucune information sur l'espèce (Thompson et Buisson 1988, Raherilalao et al. 2002). En étant une espèce à faible abondance relative dans l'ensemble des forêts humides (Raherilalao non publié), son absence dans la RS de Manongarivo au cours des recensements de 1999 est vraisemblablement liée, entre autres, aux caractéristiques aléatoires d'un inventaire rapide plutôt qu'à une distribution discontinue dans cette partie nord de l'île (Figure 1). La présence de l'espèce sur l'île de Nosy Hara constitue donc une nouvelle mention pour la distribution septentrionale de cette espèce mais aussi pour le type de forêt qu'elle fréquente ; il s'agit ainsi de la première mention récente de sa présence dans le nord où elle n'avait pas été observée depuis 1921 mais surtout d'une information inédite avec une distribution sur une petite île dans une forêt sèche de l'ouest alors que *Pseudobias wardi* était connue comme un oiseaux typique des forêts humides (Figure 2).

D'autres questions pertinentes devraient être posées sur les oiseaux de Nosy Hara, en particulier sur *Pseudobias wardi*. La mer constitue souvent une barrière écologique empêchant

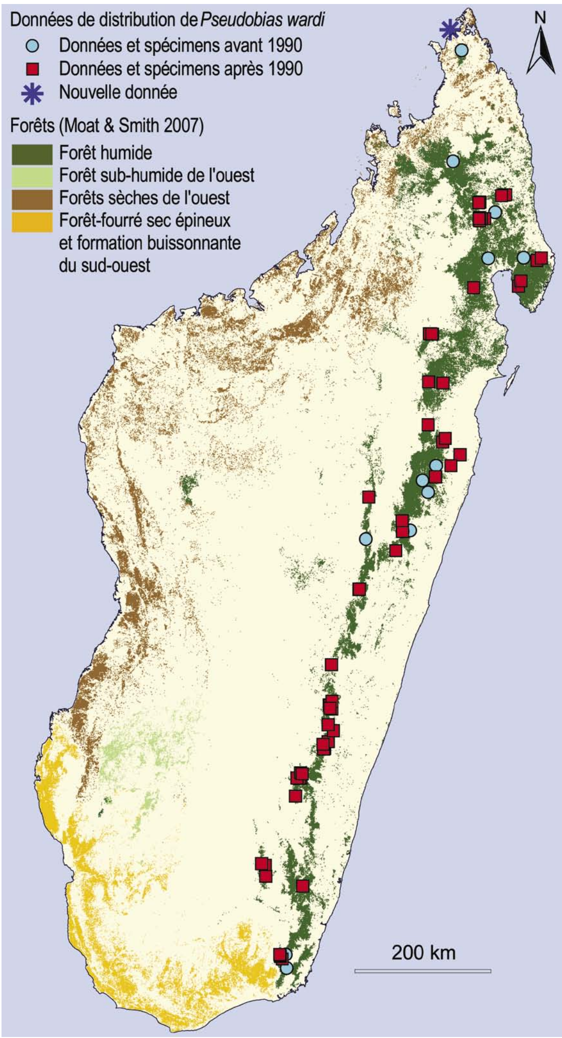

FIGURE 2. Carte illustrant la distribution connue de *Pseudobias wardi* à travers Madagascar.

le déplacement de la plupart des oiseaux forestiers comme cela pourrait être le cas pour l'espèce considérée mais aussi pour d'autres espèces des milieux ouverts ou forestiers et du sous-bois en général. Toutefois, *P. wardi* est une espèce forestière de la canopée et devait être capable de traverser une assez longue distance. Mais nous avons aussi constaté au cours de cet inventaire, que de nombreuses espèces forestières ayant des mœurs similaires ne fréquentent pas l'île. Rappelons également que la famille des Vangidae est endémique de la région avec *Cyanolanius madagascarinus* qui est également présent aux Comores, et nous avons observé une autre espèce de cette famille sur Nosy Hara (Tableau 1). La question est de savoir si nous avons affaire à une sous population qui se serait maintenue sur cette île, ou si les mouvements entre la grande terre et Nosy Hara sont plus fréquents que nous ne l'imaginons. Une étude portant sur la variabilité génétique de ces populations par rapport à celle de la grande terre pourra peut-être nous éclairer sur la question et des études plus approfondies sur ces aspects mériteraient d'être réalisées, sachant cependant qu'il conviendra au préalable de rechercher cette espèce le long de la côte de la grande terre près de Nosy Hara.

Les résultats obtenus reflètent le phénomène classique d'appauvrissement des faunes insulaires. Si on tient compte des quatre espèces rapportées par Metcaff et al. (2001) que nous n'avons pas observées lors de cette mission (*Apus melba* est une espèce nicheuse, *Corythornis vintsioides* est endémique de la région, *Charadrius pecuarius* et *Numenius phaeopus* sont des visiteurs saisonniers) sa richesse spécifique relevée est de 35 espèces. Nous avons été étonnés de constater l'absence sur Nosy Hara d'un grand nombre d'oiseaux, pourtant bons voiliers, présents sur la grande terre lors de notre passage alors que ceux-ci sont présents du côté d'Ampasindava et qu'une dizaine de kilomètres seulement séparent cette localité de Nosy Hara. Ces oiseaux pourraient être présents occasionnellement sur Nosy Hara mais n'y trouvent pas les conditions nécessaires pour y rester et il est probable que certaines des ces espèces auraient pu échapper aux observations. Des passages éventuels de ces espèces sur l'île pour chasser ne sont pas à écarter, de sorte que le nombre d'espèces inventoriées n'est probablement pas définitif car d'autres oiseaux parmi les bons voiliers connus de la grande terre pourraient visiter ces îlots. À partir de nos connaissances des oiseaux malgaches et des caractéristiques de l'archipel de Nosy Hara avec une surface relativement réduite et des facteurs écologiques similaires à ceux des forêts des calcaires et *tsingy* du versant occidental, l'archipel ne devrait pas abriter des éléments propres à lui seul. Les éléments du peuplement ornithologique rencontrés sur l'archipel sont des ubiquistes à large distribution et des espèces forestières rencontrées dans des types de forêts variés. Néanmoins, les îlots de *tsingy* sont d'une importance prioritaire en particulier pour *Haliaeetus vociferoides* qui est classée en « Danger critique d'extinction CR » selon l'IUCN (2008). Deux couples et des nids existent sur l'île et ses alentours dont un à Nosy Hara et un autre sur l'île sacrée d'Anjombavola. Metcalf et al. (2001) mentionnaient également la présence d'un autre couple et d'un autre nid de cette espèce sur l'îlot de Lakandava mais ce site de nidification aurait été abandonné depuis un certain temps selon l'équipe de New Sea Roc, un opérateur touristique travaillant sur l'îlot d'Andantsara et ses environs.

La fragilité bien connue des faunes insulaires est illustrée ici par les effectifs très réduits de certaines populations. La faible abondance relative des espèces terrestres et de sous-bois est probablement due à la densité élevée des prédateurs comme les rats (*Rattus rattus*), les boas (*Acranthophis dumerili*) et les rapaces (*Falco newtoni*). Ces prédateurs peuvent s'attaquer aux oiseaux à certains niveaux de leur développement, principalement sur les œufs et les oisillons. En outre, la taille assez réduite de l'île n'aurait probablement pas permis la survie à long terme des espèces qui ont besoin d'un grand domaine vital. Par ailleurs, cette petite superficie conjuguée à la nature de la forêt pourrait augmenter la vulnérabilité de ce groupe face à la prédation.

IMPORTANCE ET CONSERVATION

L'archipel de Nosy Hara présente des potentialités considérables sur le plan écologique, biologique, économique et socioculturel. En nous basant sur la biodiversité, l'archipel est important pour les ressources marines exceptionnelles, en particulier le récif corallien avec ses divers composants biotiques. Les plages de certains îlots constituent en outre un endroit idéal pour la ponte des tortues marines et des oiseaux comme *Sterna* spp. et les formations calcaires associées à des types de végétations adaptées à un tel substrat constituent un habitat naturel des espèces végétales et animales. Ces différents atouts ont permis au site d'accéder au rang des aires protégées marines à Madagascar. Mais la conservation d'une telle aire protégée devrait être basée sur la connaissance de la valeur biologique du site ou de la région afin de mieux suivre l'évolution parallèle entre la biodiversité, la stratégie de conservation et la gestion de cette aire protégée nouvellement mise en place.

La position géographique de Nosy Hara confère à l'île une place de premier choix pour la faune ornithologique et plus particulièrement pour les espèces migratrices qui utilisent l'île et ses environs comme un lieu de transit au cours de leur passage. Pour les oiseaux liés aux milieux aquatiques ou marins et qui se nourrissent de crabes et de poissons, les rivages de l'île constituent un endroit où ils peuvent chasser tranquillement loin des perturbations humaines. Les falaises offrent des lieux de ponte ou de repos des oiseaux de proie, comme les aigles pêcheurs, *Haliaeetus vociferoides* et pour certains oiseaux des milieux forestiers, en particulier ceux qui exploitent le sous-bois, l'île semble constituer un refuge isolé. Nous avons toutefois observé plusieurs atteintes à l'intégrité de l'environnement naturel, comme les traces de coupe des bois, le passage de feu non contrôlé dans les formations végétales aux alentours immédiats de la plage et partant de feux allumés pour fumer les poissons, les ordures laissées par les pêcheurs et touristes qui ont entraîné la prolifération des rats (*Rattus rattus*) sur l'île et enfin la collecte massive des œufs de *Sterna* spp. sur les plages de certains îlots. Ces différentes pressions ont sûrement des impacts négatifs sur la santé de l'ensemble de l'écosystème déjà fragile de l'archipel.

CONCLUSION

Bien qu'elle n'occupe qu'une superficie de 312 ha, l'île de Nosy Hara abrite une diversité biologique non négligeable, y compris les 18 espèces d'oiseaux qui ne sont pas inféodés aux milieux aquatiques. La présence de *Pseudobias wardi* dans la forêt sèche de cette île, qui n'était connue que des forêts humides lui confère une valeur scientifique inédite. Les efforts prodigués par les différentes entités œuvrant dans la conservation de cette aire protégée tel que le Projet de conservation de l'archipel de Nosy Hara du WWF constituent déjà une grande étape pour la protection de cette richesse unique dans la partie nord de Madagascar.

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Day-time feeding ecology of *Eulemur cinereiceps* in the Agnalazaha Forest, Mahabo-Mananivo, Madagascar

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ABSTRACT

The Agnalazaha Forest, a degraded fragment of littoral forest in southeast Madagascar, contains a small population of the endangered *Eulemur cinereiceps*. To better conserve this species its feeding ecology was described by habituating two groups and recording their activities, the food types and species exploited, and the location of food trees by focal animal sampling. The lemurs' environment was also described by measuring forest structure, and monitoring climate and phenology. In total, the groups were observed for 498 hours over 11 months. Monthly time spent feeding averaged 9.6 % of total observation time. The species was highly frugivorous (93 % of total time spent feeding). 55 different plant species were exploited for food. Time spent feeding and diet were not simply related to rainfall and temperature nor to food type availability. The two groups' home ranges were 54.9 ha and 58.4 ha and showed a 40 % overlap. The overlap occurred in the swamp forest, which is rich in food plants. To improve the conservation of *E. cinereiceps* at the Agnalazaha Forest, it is recommended that: The swamp forest be included within the zone of strict conservation; important lemur food plants used for restoration; and alternative sources of timber and fuel wood provided for the local population, thereby allowing greater forest regeneration.

RÉSUMÉ

La forêt d'Agnalazaha est un bloc de forêt littorale dégradée d'une superficie de 1,500 ha dans le sud est de Madagascar qui abrite une petite population de l'espèce en danger *Eulemur cinereiceps*. L'écologie de ce lémurien n'a jamais été étudiée dans les forêts littorales et pour améliorer la protection de cette espèce prestigieuse, l'écologie de son régime alimentaire a été étudiée en habituant deux groupes et en relevant la nature des activités, le type de nourriture consommé, les espèces consommées et la localisation des arbres source de nourriture par *focal animal sampling*. L'environnement d' *E.cinereiceps* a également été décrit avec des informations portant sur le climat, d'une part, et d'autres portant sur la structure de la forêt, sa composition et la phénologie en utilisant deux parcelles de 1 ha de forêt dans lesquelles tous les arbres dont le tronc avait un diamètre au moins égal à 10 cm ont été relevés, identifiés et suivis quant à leur fructification et floraison mensuelles. La structure et la composition de la forêt d'Agnalazaha se sont révélées typiques des forêts littorales malgaches. Au total, les groupes de lémuriens ont été observés pendant 498 heures au cours d'une période de 11 mois. La durée mensuelle moyenne consacrée à l'alimentation était de 9,6 % de la durée totale des observations. L'espèce s'est montrée nettement frugivore (93 % de la durée totale consacrée à l'alimentation) mais elle consommait également des feuilles, des inflorescences, des fleurs, du nectar, des insectes et des champignons. Les feuilles et les nectars ont pu être des composants importants du régime alimentaire à certaines périodes. Un total de 55 espèces de plante ont été consommées, parmi lesquelles *Noronhia emarginata, Pandanus microcephalus, Garcinia verrucosa* et *Uapaca louvelii* étaient les plus courantes. Le temps consacré à l'alimentation et celui alloué à la consommation des divers aliments n'étaient liés ni au climat ni à la disponibilité de la nourriture. Les superficies des territoires occupés par les deux groupes étaient de 54,9 ha et de 58,4 ha et présentaient un chevauchement de 40 % au niveau de la forêt marécageuse où les plantes consommées à titre de nourriture étaient abondantes. Pour protéger *E. cinereiceps* dans la forêt d'Agnalazaha, nous recommandons que la forêt marécageuse soit incluse dans une zone de conservation stricte ; que les plantes importantes faisant partie du régime alimentaire de ces lémuriens soient considérées dans les activités de restauration de la forêt ; et que des sources alternatives pour l'obtention de bois d'œuvre ou de chauffe soient proposées à la communauté villageoise locale pour permettre à la forêt de se régénérer.

KEYWORDS: Conservation, brown lemur, diet, home range, littoral forest.

MOTS CLEFS : conservation, lémur brun, régime alimentaire, territoires, forêts littorales.

INTRODUCTION

Since 2002 the Missouri Botanical Garden (MBG) has been working with local stakeholders to conserve the Agnalazaha Forest (also known as Mahabo Forest; see Hobinjatovo et al. 2009), a 1,500 ha fragment of littoral forest located in southeastern Madagascar. This site's fauna includes the endangered lemur *Eulemur cinereiceps* (IUCN 2010), whose conservation at

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Agnalazaha is important because it is a threatened part of our natural heritage that likely plays an important role in forest regeneration as a key seed dispersal. To conserve *E. cinereiceps* at this site, information is required to complement earlier studies conducted at Vevembe (Johnson 2002) and Manombo (Ralainasolo et al. 2008), neither of which examined them in littoral forest. The vegetation type comprises humid evergreen forest growing on loose sand close to the sea (Consiglio et al. 2006). The structure, flora and fauna of littoral forest differ significantly from those of humid forest located on other substrates, and it would be reasonable to expect that the ecology of *E. cinereiceps* in this habitat is likewise distinct.

The Agnalazaha Forest (E47°43'07", S23°11'10") is located in the Mahabo-Mananivo Commune, 50 km south of Farafangana (Reza et al. 2005) (Figure 1). Within the forest, two major vegetation types can be recognised based on differences in their structure and floristic composition: Swamp forest and well-drained forest. Swamp forest is located within depressions frequently inundated with fresh water in the gently undulating topography of former sand dunes, whereas the well-drained forest is located on the slopes and summits of these dunes. Swamp forest is characterised by a predominance of *Pandanus* and species of Clusiaceae, whereas the well-drained forest is characterised by the predominance of species of Sarcolaenaceae. Agnalazaha is one of the largest fragments of littoral forest remaining in Madagascar (Consiglio et al. 2006).

Around 7,000 people live in the Mahabo-Mananivo Commune and they rely heavily on the Agnalazaha Forest for a range of resources, including timber (for the construction of traditional houses), fuel, foods, medicines and materials for handicrafts (Reza et al. 2005). Fire is widely used as an agricultural tool to reduce the abundance of weeds in rice fields and to encourage young growth of grass in pastureland, and each year these activities typically result in about five wildfires within the Commune (Ludovic Reza, pers. obs.). The Agnalazaha Forest is thus mainly threatened by exploitation of timber, shifting cultivation and wildfires.

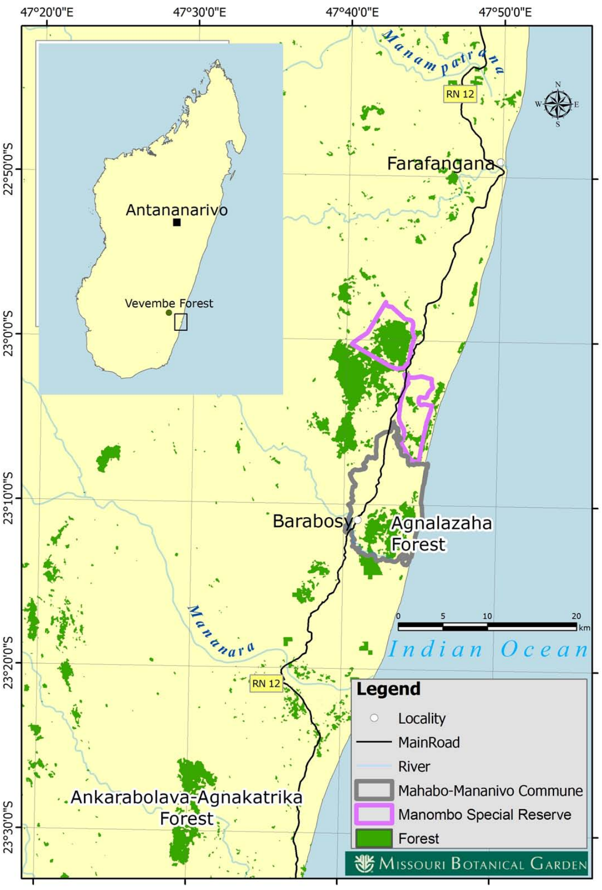

FIGURE 1. Location of the Agnalazaha Forest.

In 2007, monitoring of *Eulemur cinereiceps* in Agnalazaha Forest revealed a population of 73 individuals. Until recently, lemurs were hunted at the site by means of traps, but this activity appears to have ceased as a result of a campaign to raise awareness among local people and the implementation of local rules (called *dina*) forbidding the exploitation of lemurs. Missouri Botanical Garden and local stakeholders have formally proposed that Agnalazaha Forest be classified as a New Protected Area as part of the Malagasy Government's initiative to triple the area of the country managed primarily for nature conservation (Durbin 2006).

The current study aims to provide information on the daytime feeding ecology of *Eulemur cinereiceps* at Agnalazaha to assist the Missouri Botanical Garden and their local partners, who manage this site, so that they can meet their obligations to conserve this rare and threatened lemur and the habitat on which it depends. Although this species is cathemeral (Mittermeier et al. 2006), the study was restricted to daytime observations because local guides were reluctant to work at night in an area where wild pigs are abundant and considered aggressive, a restriction that represents an unavoidable constraint on the utility of this research.

METHODS

STUDY SPECIES. *Eulemur cinereiceps* Grandidier and Milne Edwards 1890 is regarded as synonymous with *Eulemur albocollaris* and *Eulemur fulvus albocollaris* (Rumpler 1975, Johnson et al. 2008), and is classified as Endangered (IUCN 2010). It is a medium-sized, group-living, dichromatic, cathemeral lemur with a body weight of 2-2.5 kg (Tattersall 1982, Mittermeier et al. 2006, Ralainasolo et al. 2008). It is predominantly frugivorous but also eats leaves, flowers, nectar and fungi (Johnson 2002, Ralainasolo et al. 2008). This species is reported to occur in more or less degraded littoral and escarpment humid evergreen forests in a small area in southeast Madagascar, between the Manampatrana and Mananara Rivers (Groves 2001). However, Irwin et al. (2005) report the presence of *E. cinereiceps* north of the Manampatrana River and we have recently located what appears to be a population of this species in the Ankarabolava-Agnakatrika Forest (E48°33'41", S19°08'24") just south of the Mananara River. This species is threatened by hunting and loss of habitat due to shifting cultivation, timber exploitation and wild fires (Irwin et al. 2005).

ENVIRONMENTAL DESCRIPTION. To facilitate the interpretation of this lemur's feeding ecology, their natural environment was described with regard to climate, forest structure, and the composition and phenology of the local flora.

The climate of the Agnalazaha Forest was described using data from MBG's weather station at Barabosy, a hamlet located 2 km west of the study site, outside the forest, in an anthropogenic landscape of grassland and eucalyptus plantations (see Figure 1). This station measures daily precipitation using a rain gauge and daily maximum and minimum temperature.

The forest structure was described using two one-hectare plots (Plot 1: From E47° 43' 17.5", S23° 11' 10.1", elevation 31 m to E47° 43' 04.3", S23° 11' 20.2", 49 m; Plot 2: From E47° 44' 02.4", S23° 10' 38.9", 22 m to E47° 44' 00.5", S23° 10' 39.7", 13 m), one each placed in the home range of the two lemur groups selected for study. The plots were established and censused using the methodologies described in Birkinshaw et al. (2000). Each of the 500 m × 20 m plots was oriented to include areas of both well-drained and swamp forest. Unfortunately, the significance of these two forest types in the understanding feeding ecology of the study groups was not fully appreciated until the end of the study, and the experimental design precluded analysis of data in these terms. Only trunks of trees included in the plots that had a diameter at breast height (dbh) ≥ 10 cm were considered in this study; their dbh was measured and their height estimated. Because of previous exploitation of timber within the study site, many individual trees had been coppiced and thus exhibited several trunks.

The description of floristic composition was limited to trees with dbh ≥ 10 cm located within the two plots. Each species initially was identified by scientific and vernacular names. Scientific identifications were verified and confirmed by collecting voucher herbarium specimens (following protocols described in Dold et al. 2000), and consulting the literature (e.g., the taxonomic treatments in Adansonia), specialists, and specimens in Madagascar's main herbaria. Vernacular identifications were made by consulting local people. Floristic composition was assessed by conducting an inventory of tree species, recording their respective abundances and total basal area. The Shannon diversity index (*H*) was used to compare the results of this study with those of Johnson (2002), calculated as follows:

$$H = -\sum_{i=1}^{s} (p_i)(\log p_i)$$

where s = number of species and p_i is the relative abundance of each *i*th species. Relative abundance (p_i) = N_s/N_t, where N_s is the number of trunks of the species and N_t is the number of trunks of all species.

Tree phenology was described by examining each tree in Plot 1 (N = 771) once per month with binoculars and noting the presence or absence of open flowers and/or mature fruit.

LEMUR FEEDING ECOLOGY. With the assistance of three local guides, two lemur groups (Group 1 and Group 2) were habituated to human presence. The size of each group was assessed periodically during the study by counting the total number of individuals. The feeding ecology of each group was described using 'continuous focal animal sampling' (Altmann 1974), in which an individual within the group is randomly selected and observed continuously for two hours before switching to another individual. Most observations were made between 1000h and 1600h because of the time required to locate the lemurs in the morning and the necessity of returning home before nightfall. Initially during this study, individual lemurs were identified by differences in their pelage, but in June 2006 they were captured by another group of researchers, who fitted each animal with a coloured collar. To facilitate the weekly collection of information, each lemur group was observed for three days in succession before switching to the other group. We recorded when the focal animal began and stopped each activity. Short lapses (e.g., of less than ten seconds) in an otherwise continuing activity were regarded as a cessation and resumption. Three classes of activity were recognised: Resting (which included socialising), feeding (which included foraging) and travelling. When an individual was seen feeding, the item of food being eaten was classified as ripe fruit, unripe fruit, leaves, flowers, nectar, insects, or fungi. Ripe and unripe fruit were distinguished by examining their physical characteristics and those of their seeds. For plant foods, the species was also initially identified using its vernacular name and by flagging the source plant so that a specimen could be collected to verify the identification. To define the home ranges of the two groups, the locations of the trees exploited by its members were recorded (using a global positioning system unit). These locations were then mapped using Arcview 3.2., and the area of the minimum convex polygon encompassing the locations was calculated.

RESULTS AND DISCUSSION

ENVIRONMENT. Table 1 summarises the climate at the study site. The mean minimum and maximum monthly temperature ranges from 12°C to 20°C and 27°C to 34°C, respectively. The total precipitation for the 11-month period October 2006 to August 2007 (data are missing for September 2006 because of equipment failure) was 3,144 mm. Although temperatures are high and there is some precipitation in every month of the year, the climate was hottest between November and March and wettest between January and May.

The density of trees in the Agnalazaha Forest was estimated as 809 trunks per hectare. A total of 88.2 % of the trunks were in the diameter class 10-20 cm; mean trunk diameter

TABLE 1. Climate at Barabosy and flowering and fruiting phenology of 1,618 trunks included in the two plots (m: missing data point).

Months	Mean temperature (°C)		Precipitation (mm)	Number of trunks in plots	
	Minimum	Maximum		with flowers	with fruit
VI 2006	16.4	31.6	0	0	0
VII 2006	15.6	26.7	223	36	59
VIII 2006	15.6	27.3	173	45	61
IX 2006	13.5	27.8	m	49	52
X 2006	m	m	29	40	28
XI 2006	17.6	34.0	171	61	46
XII 2006	19.7	33.8	48	94	56
I 2007	20.2	33.2	784	103	61
II 2007	19.5	34.0	587	117	60
III 2007	19.5	33.2	589	126	59
IV 2007	18.3	31.1	345	124	64
V 2007	16.0	29.5	319	126	70
VI 2007	12.9	28.0	139	m	m
VII 2007	12.9	29.0	68	m	m
VIII 2007	11.7	30.9	65	m	m
IX 2007	m	m	m	m	m
X 2007	m	m	m	m	m
XI 2007	m	m	m	m	m
XII 2007	m	m	m	m	m
I 2008	19.7	34.0	332	m	m
II 2008	19.0	31.7	492	m	m
III 2008	18.0	33.3	291	m	m
IV 2008	16.8	30.2	314	m	m
V 2008	14.4	27.5	335	m	m

was 14.6 cm and maximum dbh was 48.2 cm. The average tree height was 9.7 m and the total trunk basal area was 30.1 m^2 per hectare. Rabevohitra et al. (1998) described the flora and structure of littoral forest in ten one-hectare plots established at five sites distributed along the east coast of Madagascar. They report that trunk density ranged from 542 to 1,221 trunks per ha, total trunk basal area from 19.03 to 38.9 m^2, and mean tree height from 9.92 to 12.56 m. Thus, the structure of the Agnalazaha Forest can be considered as typical of Malagasy littoral forest in its current state. However, it should be noted that all remaining areas of this vegetation type in Madagascar have been subjected, to a greater or lesser extent, to anthropogenic pressures, and its natural structure was almost certainly different (Consiglio et al. 2006).

Compared to the Vevembe Forest, the evergreen humid forest on basement rock where Johnson (2002) conducted his ecological study of *Eulemur cinereiceps*, Agnalazaha Forest has a lower trunk density, a lower canopy height, a smaller mean trunk size and a lower trunk basal area per unit area (see Table 2). These differences likely reflect the geology of the two sites as well as the higher level of forest degradation at Agnalazaha. Forest structure cannot be compared between the Agnalazaha Forest and the evergreen humid forest on lava at Manombo, the study site for Ralainasolo et al. (2008), because of fundamental differences in the methods used in these studies.

Among the 1,618 trunks included in the plots at Agnalazaha, a total of 145 species were recorded. The most speciose families were: Salicaceae (with 14 species), Clusiaceae (12 species), Euphorbiaceae (11 species), Myrtaceae (10 species), Anacardiaceae (8 species), and Ebenaceae (8 species). The value of the Shannon diversity index is 1.659. The species with the highest trunk abundance and trunk basal area were: *Intsia bijuga* (Fabaceae, 12.5% of total trunks, 12.2% total trunk basal area), *Anthostema madagascariensis* (Gentianaceae, 8.1%, 7.4%); *Uapaca louvelii* (Euphorbiaceae, 7.2%, 9.4%); *Asteropeia multiflora* (Asteropeiaceae, 5.4%, 4.9%); *Brochoneura acuminata* (Myristicaceae, 4.4%, 3.9%); and *Agarista salicifolia* (Ericaceae, 1.9%, 4.8%). At each of the five littoral forest sites studied by Rabevohitra et al. (1998) the number of tree species recorded in the pair of one-hectare plots ranged from 60 to 144. Thus, with 145 tree species per hectare, the Agnalazaha Forest can be considered relatively species rich. Johnson (2002) reports 60 species among the 267 trunks included in the plots established at Vevembe Forest, with a Shannon diversity index ranging from 1.072 to 1.269 (among four plots, each with a size of 0.0625 ha). Because of the different sample sizes used by Johnson (2002) and the current study it is difficult to compare species diversity between the two sites. A comparison of floristic composition between the forests at Agnalazaha and Manombo (Ralainasolo et al. 2008) is also difficult because of the different dbh classes recorded in the two studies.

TABLE 2. Comparison of forest structure between Vevembe Forest (Johnson 2002) and Agnalazaha Forest.

Study Site	Johnson (2002) Vevembe Forest	This study Agnalazaha Forest
Trunk density [per ha]	1,068 (based on area of 0.25 ha)	809 (based on area of 2 ha)
Mean trunk dbh [cm]	18.4 (N = 267)	14.6 (N = 1,618)
Trunk basal area [m²/ha]	35.8 (based on area of 0.25 ha)	30.1 (based on area of 2 ha)
Mean tree height [m]	12.5 (N = 267)	9.7 (N = 1,618)

Table 1 shows the number of trees in the two Agnalazaha plots bearing flowers and fruits during the period July 2006 to May 2007. Approximately three times the number of trees flowered between December 2006 and May 2007 compared to the period July to November 2006. The phase of maximum flowering coincides with the period of highest precipitation. The number of trees with fruit was nearly constant throughout the study period except during October 2006, when few trees carried fruit. October was also the month with lowest precipitation.

FEEDING ECOLOGY. In total, Group 1 was observed for 229 hours distributed over nine months and Group 2 for 269 hours distributed over 11 months. Group 1 could not be located during the months of February and March 2007 and data are therefore lacking from this period. We suspect that this group had left the area where hitherto it had been located and was instead feeding on the nectar of *Ravenala madagascariensis*, which is abundant elsewhere and was flowering at this time. During the study, the size of Group 1 ranged from five to seven individuals, while Group 2 comprised from nine to eleven individuals.

Table 3 shows the percentage of total observation time that Group 1 and Group 2 respectively spent feeding, travelling and resting during each month from June 2006 to May 2007. For both groups, during every month, a majority of their time was spent resting (55-85% total time); time spent feeding ranged from 2% to 22%, and travelling occupied from 7% to 23% of the time. During most months, Group 1 spent more

TABLE 3. Percentage of total observation time that Group 1 and Group 2 spent feeding, travelling and resting during each month of the study (m: missing data point).

Month	Group	Observation time [min]	% total observation time spent on each activity		
			Feeding	Travelling	Resting
VI 2006	1	1,187	14.0	13.5	72.5
	2	1,244	6.6	16.0	77.4
VII 2006	1	2,293	14.4	14.0	71.6
	2	675	10.0	16.7	73.3
VIII 2006	1	0	m	m	m
	2	0	m	m	m
IX 2006	1	2,606	7.4	16.0	76.6
	2	1,031	9.3	7.1	83.6
X 2006	1	1,999	8.8	16.4	74.9
	2	1,106	9.0	17.9	73.1
XI 2006	1	1,641	14.3	14.7	71.0
	2	1,318	5.3	13.9	80.8
XII 2006	1	1,022	15.4	22.0	62.6
	2	1,063	4.9	10.2	85.0
I 2007	1	896	21.5	23.3	55.1
	2	654	6.3	20.3	73.4
II 2007	1	0	m	m	m
	2	2,444	9.9	14.4	75.8
III 2007	1	0	m	m	m
	2	2,626	9.8	15.7	74.5
IV 2007	1	1,460	10.1	23.4	66.5
	2	3,138	6.0	17.3	76.7
V 2007	1	623	7.6	17.1	75.3
	2	893	1.8	17.9	80.3

time feeding than Group 2. For both groups, time spent feeding fluctuates through the year, but the pattern of fluctuation differs between the groups: For Group 1, a relatively large amount of time was spent feeding from November 2006 to January 2007 and from June to July 2006, whereas for Group 2 peaks in time spent feeding occur between July to October 2006 and February to March 2007.

The average monthly time spent feeding by *Eulemur cinereiceps* at Agnalazaha is 9.6 %, lower than the values reported for this species by both Johnson (2002) at Vevembe (12-15 %) and Ralainasolo et al. (2008) at Manombo (12 %). The lower value found at Agnalazaha may result from the fact that most observations of feeding ecology were made between 1000h and 1600h, which could have led to an under-representation of possible early morning and late afternoon feeding periods. However, Johnson (2002) and Ralainasolo et al. (2008) do not mention the distribution of their observations during the day.

Table 4 shows the percentage of total time that Group 1 and Group 2 spent feeding on different types of food. For both groups, during every month of the study, the diet was dominated by ripe fruit, with the percentage of total monthly feeding time allocated to this food type ranging from 63 % to 100 %. Combining the data from the two groups reveals that at Agnalazaha *Eulemur cinereiceps* is strongly frugivorous (93 % of feeding time). A variety of other food types were important secondary dietary constituents at certain times of the year, including unripe fruits for Group 1 in June 2006, leaves for Group 1 for September 2006, and nectar for Group 2 in May 2007. It is possible that nectar was also an important food item for Group 1 during February and March 2007, when the Group could not be found where it was normally located, and on the basis of observations made by local people, is thus suspected to have been feeding on nectar of *Ravenala madagascariensis* elsewhere . Rare foods included insects and fungi.

Eulemur cinereiceps was considerably more frugivorous in the Agnalazaha Forest (93 %) than at Vevembe (66 %) or Manombo (67 %) (Johnson 2002, Ralainasolo et al. 2008), a finding that may reflect the different seasons during which these studies were conducted. The high frugivory observed at Agnalazaha Forest is similar to that reported for the hybrid *E. cinereiceps* × *E. fulvus rufus* (95 % of feeding time) at Andringitra (Johnson 2002). According to Johnson (2002), levels of frugivory reported for brown lemurs range from 67 % to 89 % (with the exception of the mainly folivorous groups of *E. fulvus rufus* studied by Sussman (1974, 1977)). Given the partially degraded state of the Agnalazaha Forest, the high level of frugivory of *E. cinereiceps* was unexpected. Food categories less important for *E. cinereiceps* (i.e., unripe fruit and leaves) also contribute to the diets of brown lemur populations elsewhere (Johnson 2002, Ralainasolo et al. 2008), although typically these items have been found to be of greater importance in these studies than is the case in the current study.

The time spent feeding by the two lemur groups at Agnalazaha Forest was not related in any simple way to availability of broadly defined food type classes or to precipitation. For example, the time spent feeding was relatively high for Group 2 in both September 2006 (a time with low precipitation

TABLE 4. Percentage of total feeding time that Group 1 and Group 2 spent feeding on different food types during each month of the study. (* time spent feeding during observation time).

Month	Time* [min]	Group	% time spent feeding on food type						
			Ripe Fruits	Unripe Fruits	Leaves	Flowers	Insects	Nectar	Fungi
VI 2006	166	1	79.1	18.4	2.5	0.0	0.0	0.0	0.0
	82	2	90.1	2.8	7.0	0.0	0.0	0.0	0.0
VII 2006	330	1	96.8	0.0	1.9	1.0	0.3	0.0	0.0
	75	2	100.0	0.0	0.0	0.0	0.0	0.0	0.0
VIII 2006	0	1	m	m	m	m	m	m	m
	0	2	m	m	m	m	m	m	m
IX 2006	194	1	73.6	0.0	22.3	4.1	0.0	0.0	0.0
	83	2	100.0	0.0	0.0	0.0	0.0	0.0	0.0
X 2006	175	1	86.2	4.6	6.9	2.3	0.0	0.0	0.0
	99	2	98.0	0.0	2.0	0.0	0.0	0.0	0.0
XI 2006	235	1	98.7	0.0	0.4	0.0	0.9	0.0	0.0
	70	2	100.0	0.0	0.0	0.0	0.0	0.0	0.0
XII 2006	157	1	91.0	9.0	0.0	0.0	0.0	0.0	0.0
	53	2	100.0	0.0	0.0	0.0	0.0	0.0	0.0
I 2007	184	1	91.1	4.5	0.0	0.7	2.8	0.0	0.9
	42	2	93.8	3.1	0.0	0.0	3.1	0.0	0.0
II 2007	0	1	m	m	m	m	m	m	m
	234	2	98.3	0.0	0.4	0.9	0.4	0.0	0.0
III 2007	0	1	m	m	m	m	m	m	m
	258	2	86.6	2.8	1.6	1.2	0.4	7.3	0.0
IV 2007	146	1	83.2	3.8	2.3	1.5	0.8	8.4	0.0
	186	2	78.6	0.0	11.9	1.8	2.4	5.4	0.0
V 2007	47	1	89.5	0.0	2.9	3.9	1.9	1.8	0.0
	16	2	62.5	0.0	0.0	6.3	6.3	25.0	0.0

and low fruit availability) and February 2007 (high precipitation and high fruit availability). Also, the diet of the two lemur groups does not seem to be related simply to the availability of fruit or of flowers, nor to the amount of precipitation. In September 2006, when fruit was least available, Group 1 spent more time eating leaves than in any other month, yet during this same month, Group 2 was 100 % frugivorous. Furthermore, when fruit was most available in May 2007, Group 2 spent more time exploiting nectar than in any other month. This observation suggests that nectar should not be regarded as a less preferred food type than fruit. Johnson (2002) also found that his study groups did not track resources in predictable ways.

Table 5 lists the plant species eaten by the two groups. In total, food from 55 different plant species was consumed. Table 6 lists the most important food for the two groups, defined as items consumed for ≥ 10 % of total time spent feeding during a given month. Food that is frequently listed include ripe fruits of *Noronhia emarginata, Pandanus microcephalus, Garcinia verrucosa* and *Uapaca louvelii*. The fruits from two alien species (*Clidemia hirta* and *Psidium cattleianum*) were also exploited by the lemurs.

TABLE 5. Plant species and plant parts exploited by the two study groups of *Eulemur cinereiceps* at Agnalazaha Forest.

Family	Species	Vernacular Name	Part Consumed	Group	
				1	2
Anacardiaceae	*Abrahamia* sp. 1.	Tarata lahy	fruits		X
Annonaceae	*Ambavia gerrardii*	Rombavy	fruits	X	X
Annonaceae	sp. 1.	Fotsivavy	leaves		X
Asclepiadaceae	*Secamone* sp. 1.	Vahisisika	leaves	X	
Arecaceae	*Dypsis linearis*	Vonitra	fruits		X
Arecaceae	*Dypsis mananjariensis*	Varaotra	fruits	X	X
Bignoniaceae	*Colea* sp 1.	Fotsitsoy	fruits	X	X
Bignoniaceae	*Phyllarthron madagascariensis*	Retsirika	flowers	X	X
Canellaceae	*Cinnamosma madagascariensis*	Fotsignana	fruits	X	X
Clusiaceae	*Calophyllum milvum*	Vitagno	fruits + leaves	X	X
Clusiaceae	*Garcinia verrucosa*	Tsingarahara	fruits	X	X
Clusiaceae	*Psorospermum* sp 1.	Haronganala	fruits	X	
Ebenaceae	*Diospyros ferrea*	Ramagnopaka	fruits		X
Erythroxylaceae	*Erythroxylon* sp. 1.	Sakainala	fruits	X	
Euphorbiaceae	*Uapaca louvelii*	Voapaky	fruits	X	X
Euphorbiaceae	*Uapaca* sp.1.	Voapaky lahy	fruits		X
Fabaceae	*Intsia bijuga*	Hintsy	leaves + fruits	X	X
Icacinaceae	*Cassinopsis* sp. nov.	Hazomafaitra	fruits	X	X
Lamiaceae	*Clerodendrum* sp. 1.	Tarata	fruits	X	X
Lamiaceae	*Vitex chrysomallum*	Sarivatoa beravina	fruits	X	
Lamiaceae	*Vitex oscitans*	Sarivatoa	fruits	X	
Loranthaceae	*Bakerella* sp. 1.	Velomihato	leaves		X
Melastomataceae	*Clidemia hirta*	Voatrotrakala	fruits	X	
Melastomataceae	*Tristemma virusanum*	Voatrotroka	fruits	X	
Meliaceae	*Astrotrichilia* sp. 1	Sagnira	fruits		X
Menispermaceae	*Burasaia australis*	Mafanakelika	fruits	X	
Moraceae	*Ficus lutea*	Amontana	fruits		X
Moraceae	*Ficus rubra*	Laza	fruits	X	X
Moraceae	*Ficus tiliifolia*	Ara	fruits		X
Myrsinaceae	*Embelia incumbens*	Masomazava	fruits		X
Myrsinaceae	*Monoporus spathulatus*	Varikanda	flowers		X
Myrtaceae	*Psidium cattleianum*	Goavy	fruits	X	X
Myrtaceae	*Syzygium* sp. 1	Rotra	fruits		X
Oleaceae	*Jasminum kitchingii*	Vahimavo	fruits	X	X
Oleaceae	*Noronhia emargnata*	Randra	fruits	X	X
Oleaceae	*Noronhia* sp. 1	Randra beravina	fruits	X	
Pandanaceae	*Pandanus* sp. 1	Farafatrala	fruits	X	X
Pandanaceae	*Pandanus microcephalus*	Tsirika	Fruit + flowers	X	X
Pteridaceae	*Pteridium aquilinum*	Tsipang-ampaga	leaves	X	X
Rubiaceae	*Antirhea borbonica*	Hazomalefaka	fruits	X	X
Rubiaceae	*Coffea resinosa*	Sarikafe	fruits	X	
Rubiaceae	*Enterospermum* sp. 1	Apody	fruits	X	X
Rubiaceae	*Gaertnera* sp. 1	Sarikafenala	fruits	X	
Rubiaceae	*Pyrostria* sp. 1	Fotsikahitra	fruits	X	X
Rubiaceae	*Saldinia* sp. 1	Sarikafe manga	fruits	X	X
Salicaceae	*Scolopia erythrocarpa*	Fotsivogny	leaves	X	
Sapindaceae	*Filicium thouarsianum*	Sagnira lahy	fruits	X	
Sapindaceae	*Tinopsis conjugata*	Sagnira	fruits		X
Sarcolaenaceae	*Leptolaena pauciflora*	Fatra	fruits	X	
Sarcolaenaceae	*Sarcolaena multiflora*	Hela	fruits	X	X
Solanaceae	*Solanum* sp. 1	Anamamy	fruits	X	
Streliziaceae	*Ravenala madagascariensis*	Ravinala	nectar	X	X
Unknown	Unknown	Hazomaimbo	fruits	X	
Unknown	Unknown	Vatoadambo	fruits	X	
Unknown	Unknown	Hazonoaty Kely	leaves	X	

TABLE 6. Main food items for the two study groups of *Eulemur cinereiceps* at Agnalazaha Forest.

Month	Group 1			Group 2		
	Species	Food Type	% total feeding time	Species	Food Type	% total feeding time
VI 2006	*Ambavia gerrardii*	Ripe fruit	67	*Ambavia gerrardii*	Ripe fruit	65
	Pandanus sp. 1	Unripe fruit	10	*Dypsis linearis*	Ripe fruit	19
VII 2006	*Ficus rubra*	Ripe fruit	37	*Noronhia emarginata*	Ripe fruit	79
	Noronhia emarginata	Ripe fruit	15	*Ficus tiliifolia*	Ripe fruit	10
	Vitex oscitans	Ripe fruit	13			
	Uapaca louvelii	Ripe fruit	13			
	Pandanus sp. 1	Ripe fruit	11			
VIII 2006						
IX 2006	*Noronhia emarginata*	Ripe fruit	37	*Noronhia emarginata*	Ripe fruit	51
	Uapaca louvelii	Ripe fruit	27	*Uapaca louvelii*	Ripe fruit	49
	Secamone sp. 1	Leaves	10			
X 2006	*Noronhia emarginata*	Ripe fruit	11	*Noronhia emarginata*	Ripe fruit	28
	Garcinia verrucosa	Ripe fruit	11	*Uapaca louvelii*	Ripe fruit	25
	Pandanus microcephalus	Ripe fruit	58	*Pandanus microcephalus*	Ripe fruit	19
				Uapaca sp. 1	Ripe fruit	14
				Calophyllum milvum	Ripe fruit	10
XI 2006	*Garcinia verrucosa*	Ripe fruit	37	*Garcinia verrucosa*	Ripe fruit	65
	Pandanus microcephalus	Ripe fruit	23	*Pandanus microcephalus*	Ripe fruit	12
	Tristemma virusanum	Ripe fruit	18	*Calophyllum milvum*	Ripe fruit	12
	Cinnamosma madagascariensis	Ripe fruit	12			
XII 2006	*Abrahamia* sp. 1	Ripe fruit	36	*Pandanus microcephalus*	Ripe fruit	77
	Garcinia verrucosa	Ripe fruit	10	*Garcinia verrucosa*	Ripe fruit	24
I 2007	*Coffea resinosa*	Ripe fruit	57	*Abrahamia* sp. 1	Ripe fruit	71
	Psorospermum sp. 1	Ripe fruit	14	*Pandanus microcephalus*	Ripe fruit	13
				Embelia incumbens	Ripe fruit	10
II 2007				*Pandanus microcephalus*	Ripe fruit	45
				Astrotrichilia sp. 1	Ripe fruit	27
				Abrahamia sp. 1	Ripe fruit	19
III 2007				*Syzygium* sp. 1	Ripe fruit	47
				Dypsis mananjariensis	Ripe fruit	19
IV 2007	*Pyrostria* sp. 1	Ripe fruit	61	*Pyrostria* sp. 1	Ripe fruit	57
	Antirhea borbonica	Ripe fruit	11	*Dypsis mananjariensis*	Ripe fruit	13
				Calophyllum milvum	Young leaves	12
V 2007	*Pyrostria* sp. 1	Ripe fruit	47	*Dypsis mananjariensis*	Ripe fruit	63
	Dypsis mananjariensis	Ripe fruit	21	*Ravenala madagascariensis*	Nectar	27

The estimated dietary diversity of *Eulemur cinereiceps* in the Agnalazaha Forest was considerably less than at Vevembe (55 versus 96 plant species), despite the fact that two groups were studied for nine and 11 months, respectively, at Agnalazaha whereas only one group was studied at Vevembe for five months. However, at Manombo, Ralainasolo et al. (2008) reported similar dietary diversity for *E. cinereiceps* as our findings indicate at Agnalazaha, with 54 plant species being exploited during their nine-month study. It is likely that the comparatively low dietary diversity of *E. cinereiceps* at Agnalazaha compared to Vevembe is related to the higher degree of frugivory shown by this species at the former site. Johnson (2002) also reports lower dietary diversity for highly frugivorous *E. cinereiceps* × *E. fulvus rufus* at Andringitra (69 and 27 species, respectively, for two study groups) than for *E. cinereiceps* at Vevembe. However, this does not explain the lower dietary diversity at Manombo compared to Vevembe, where *E. cinereiceps* showed a similar degree of frugivory. It is also possible that the dietary diversity of *E. cinereiceps* at Agnalazaha is lower now than it once was because some plant species have become increasingly rare or have been extirpated as a result of heavy exploitation by humans. For example, several genera of Sapotaceae (e.g., *Capurodendron*, *Faucherea* and *Sideroxylon*) with large fleshy fruits that are included in the diets of *E. cinereiceps* at Manombo (Ralainasolo et al. 2008) and Vevembe (Johnson 2002) are, according to elderly residents living close to Agnalazaha Forest, much more rare now than in the past because they have been exploited for their valuable timber.

Table 6 shows that during several months the two groups of *Eulemur cinereiceps* at Agnalazaha spent more than 50 % of their time feeding on the fruit of a single species. This contrasted with the situation at Vevembe, where for each month of the study much less time was spent eating the most important food item (the maximum being August 2000, when the group spent 35.6 % of its time eating *Pandanus* flowers). However, the apparent frequent dominance of one food item in monthly diets at Agnalazaha may be due to the relatively short monthly observation times for each group at this site. At both Agnalazaha and Vevembe, *Pandanus* species were identified as being among the most important food items. The fruits of this genus are also reported in the diet of *E. cinereiceps* at Manombo (Ralainasolo et al. 2008).

The home ranges of Group 1 and Group 2 measured during the study period are 54.9 ha and 58.4 ha, respectively. However, as mentioned above, in February and March 2007, Group 1 could not be found in the part of the forest where it was normally located, and we have deduced that it was probably spending long periods outside this area, in which case the home range for this group would be considerably larger than indicated above. Johnson (2002) reports a home range of 33.5 to 64.3 hectares (depending on method of estimation used) for his group at Vevembe, and provides a literature review of home range estimates for brown lemurs that reveals a huge variation, from 0.75 ha to 100 hectares.

There is a 40 % overlap between the home ranges of the two study groups at Agnalazaha, and most of this overlap coincides with the swamp forest, where many of the species most frequently exploited for food are located (including *Calophyllum milvum, Ficus rubra, Garcinia verrucosa, Pandanus* spp, *Ravenala madagascariensis*, and *Uapaca louvelii*). A third group of *Eulemur cincereiceps* was also observed on occasion in the swamp forest. Johnson (2002) similarly reports high home range overlap between groups of *E. cinereiceps* at Vevembe and refers to studies of other brown lemur species in which similar ranging patterns have been found.

RECOMMENDATIONS FOR IMPROVING THE CONSERVATION STATUS OF *EULEMUR CINEREICEPS* AT AGNALAZAHA FOREST.

Based on the results presented in this study, we formulate a number of recommendations to improve the conservation status of *Eulemur cinereiceps* at the Agnalazaha Forest, as follows:

1. Further research is required to test the hypothesis that areas of swamp forest are of critical importance for *E. cinereiceps* in the Agnalazaha Forest. In the meantime, further degradation of these areas from ongoing timber extraction should be avoided and their regeneration encouraged. In particular, these areas should be included in the 'zone of strict conservation' of the proposed New Protected Area.
2. Several plants are of particular importance as food for *E.cinereiceps*, including *Noronhia emarginata, Pandanus microcephalus*, *Garcinia verrucosa*,*Uapaca louvelii*, and perhaps also *Ravenala madagascariensis*. We recommend that these species should be included among those chosen for forest restoration at Agnalazaha Forest. Species of Sapotaceae, whose fruits were likely once heavily exploited by lemurs but are now rare due to over-exploitation, should also be considered for inclusion in programmes of forest restoration.
3. In general, it would appear that *E. cinereiceps* is an adaptable species that has been able to survive in Agnalazaha Forest despite its partially fragmented and degraded condition. *Eulemur* species seem to recover rapidly from perturbations to their habitat (Ratsisetraina 2006, Ralainasolo et al. 2008) and it is likely that the current small population of *E. cinereiceps* at Agnalazaha would increase rapidly if the current levels of timber extraction are reduced and the forest is able to regenerate. Such a population increase should be encouraged because the long-term viability of this and other species at this site will remain questionable as long as the population of *E. cinereiceps* remains small.

CONCLUSIONS

Despite the partially degraded condition of the Agnalazaha Forest, its resident populations of *Eulemur cinereiceps* are highly frugivorous. In addition to fruit, other food types consumed include leaves, inflorescences, flowers, nectar, insects and fungi, and of these, leaves and nectar may be important dietary constituents at certain times. Although 55 plant species are exploited for food, the diet of *E. cinereiceps* is dominated by 25 of these species. Although the two groups studied at Agnalazaha had home ranges of at least 55 ha and 58 ha, respectively, most of the plants exploited for food were located in an area of swamp forest where the home range of these groups overlapped. These results suggest that the conservation of *E. cinereiceps* at Agnalazaha can be improved by:

(i) including the swamp forest in the 'zone of strict conservation' of the proposed new protected area so that it can regenerate following years of over-exploitation;

(ii) by incorporating important lemur food plants in efforts to restore very degraded forest; and

(iii) by activities that result in reduced exploitation of the forest for timber and fuel, including, most importantly, the provision of alternative resources.

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INTERVIEW MADAGASCAR CONSERVATION & DEVELOPMENT

Independent Forest Monitoring Madagascar

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REINER TEGTMEYER

Please introduce yourself briefly – how are you related with Madagascar's forests? In your opinion, why are forests important?

I work with the London-based NGO Global Witness as their International Forest and Independent Forest Monitoring (IFM) Expert. I was responsible for the implementation of an Independent Forest Monitoring project in Cameroon, from 2002 to 2005; developed and initiated IFM projects in Honduras and Nicaragua; trained NGOs in IFM methodology and techniques in Indonesia, Liberia and DRC; and carry out investigations into illegal logging and industrial-scale logging, mainly in African countries.

Forests cover more than a tenth of our planet and play a significant role in providing ecosystem services such as global climate regulation and mitigation, and steady local and regional water supply. Not only are forests biodiversity hotspots but almost all are inhabited by people whose livelihoods, customs and cultures are forest-dependent. However, most states have adopted the appropriation of communal land during colonial times by declaring them state property or trust land centrally managed by the government on the people's behalf. Consequently, forests are being designated for a wide range of 'external uses': Industrial-scale logging, conversion into agricultural plantations, clearing for minerals and oil exploitation and settlement for people that have been relocated (often those pushed out of other forests). Under the pretext of contributing to development, donors such as the World Bank promote the adoption of policies that support industrial land use in countries that are forest-rich but extremely poor. This has had detrimental impacts on forest peoples' livelihoods and economic prospects, often forcing them from their homes and traditional lands.

In July 2009, Global Witness was invited by Madagascar National Parks (MNP) to assist them in investigating the illegal harvest of precious wood in the SAVA Region, and the associated international trafficking of illegal timber. In August 2009, I carried out investigative work in Marojejy and Masaola National Parks, Antahala, Vohemar and Antananarivo together with a colleague from the Environmental Investigation Agency (EIA-US), Adam Khedouri. We are still doing more investigations into the traffickers and buyers of the illegal wood.

Where do you see current and future challenges in managing and conserving Madagascar's forests?

I see the lack of technical competence and capacity of the relevant authorities as the major challenge in forest management and conservation in Madagascar, including the understaffing of local forest administrations. This is partly the result of a lack of political will at both the central and provincial level to implement the forest management principles and procedures that were developed with assistance of the United States Agency for International Development (USAID). Ensuring that forest and protected area management benefits the Malagasy population also poses a challenge. This means achieving revenue generation and protection of Madagascar's unique biodiversity through the development of a coherent land use policy, which coordinates agriculture, mining, forestry, plantation and conservation interests.

What do you think of an Independent Forest Monitoring (IFM) system to help forest governance in Madagascar to deal with the challenges you mentioned?

Independent Forest Monitoring (IFM) is a monitoring approach through which an independent third party assists a government in making law enforcement efficient, effective and transparent. As such IFM is a governance tool providing oversight of forest sector activities and assuring the rights of peoples living in and dependent upon forests. It is not a special Technical Assistance project providing capacity building and other forest sector policy support. Under these premises IFM can play a powerful role in improving governance in the forest sector through identifying weaknesses in the forest management and control systems, exposing illegal activities and corruption and those responsible ('naming and shaming'), making relevant recommendations for remedial actions and publishing results of the various IFM activities.

However, IFM should not be used to criminalize forest-dependent people or small-scale farmers through the application of laws that don't take into account the needs of the poor to make a decent living, or respect their traditional and user rights.

Who would you like to see participating in such an IFM and how could it be funded?

IFM should ideally be carried out by representatives of local civil society (e.g., Alliance Voahary Gasy = AVG, FANAMBY). However, due to lack of relevant experience, knowledge and skills, IFM might be initiated by an international NGO with expertise in IFM, working in official partnership with an official institution, for example the National Environment and Forest Sector Observatory (*Observatoire National de l'Environnement et du Secteur Forestier* = ONESF) and in close collaboration with Malagasy civil society. The IFM experts could carry out capacity building for selected civil society representatives and on-the-job training for the official partner in order to secure sustainability of IFM. Funding could initially be provided by the international development assistance partners of the Malagasy Government but eventually should come from the government budget. Studies show that the gains achieved through IFM in reducing illegal logging outweigh its costs.

ANDREA JOHNSON

Please introduce yourself briefly – how are you related with Madagascar's forests? In your opinion, why are forests important?

My name is Andrea Johnson. I'm currently the Director of Forest Campaigns for the U.S. office of the Environmental Investigation Agency (EIA). EIA is a non-profit advocacy organization based in London and Washington, DC, which for 25 years has worked to investigate and expose environmental crimes such as wildlife trafficking, chemicals smuggling and illegal logging, and campaign for solutions. We became involved with Madagascar's forests in 2009 when illegal logging surged in the wake of the political coup, and EIA (together with our longtime ally Global Witness) was invited in by Madagascar National Parks to conduct an investigation of the situation and provide recommendations on how to address it. Our initial report, "Investigation into the Illegal Felling, Transport and Export of Precious Wood in SAVA Region, Madagascar", was published in October 2009; we continue to conduct follow up research and advocacy.

The forests of Madagascar and elsewhere are particularly compelling to me and to EIA because of the way that complex economic, social, biological, and ultimately moral issues intersect within the trees. 'For what' and 'for who' are vital questions we constantly must ask in this struggle over how to protect and responsibly manage forest ecosystems – and answering them is so important to millions of species, to human health and livelihoods, to the global climate.

Where do you see current and future challenges in managing and conserving Madagascar's forests?

One of Madagascar's principal challenges – by no means the only one, but one of the most pernicious – is illegal logging and the economic and political system that perpetuates it. At the time of our research last year, evidence suggested that hundreds of loggers were extracting 100-200 rosewood (*Dalbergia* spp.) trees *daily* from just the Mananara Biosphere Reserve and Masoala National Park; a previous wave of logging had invaded Marojejy National Park. This kind of logging, while selective, causes a variety of knock-on effects and has serious impacts on animal habitat, floral diversity and composition.

Logging for rosewood or ebony (*Diospyros* spp.) three days' walk into a national park is not something that local people do to build their own homes. This logging is financed by a select group of economic elite, 'timber barons'; our and others' research have shown that these men operate essentially with legal impunity, contributing to a pervasive sense of collusion and cyclical legalization of illegal activity. And ultimately the timber barons' businesses are driven by demand from foreign markets – according to our research, principally Chinese furniture makers but also industries including musical instruments in the US and Europe. These markets are so disconnected from the forest that it's difficult for consumers to link their purchases to causing harm to lemurs or local livelihoods. New laws and policies such as the US Lacey Act, which establishes stiff penalties for trading in illegally-sourced wood products, are beginning to induce greater responsibility down the supply chain (for example, the company Gibson Guitars is currently being investigated in the US for importing illegal Madagascar precious woods). However, in Madagascar the combination of a poor populace eager for the kind of cash-wage work that illegal logging provides, systemic corruption among poorly-paid officials and the political leaders financed by timber barons, and finally a no-questions-asked foreign market, has proved to be a tough cycle to break.

Another complex challenge that Madagascar seems to face is how to integrate forests into economic development in a manner more sustainable than either pure extraction or pure tourism. To be clear, tourism can be an important motivation for protecting forests. But Madagascar is remote and politically unstable, and tourism is a notoriously fickle industry. Neither is foreign aid a long-term answer. To have forests around in the long term, the people living in and around the forests must believe there's value to keeping them there and to defending them.

These challenges have a unique Malagasy flavor from the island's particular geography and historical development, but there are other resource-rich, governance-poor nations with a similar confluence of problems. We can learn from other countries' experiences in approaching how to make things better in Madagascar.

What do you think of an Independent Forest Monitoring (IFM) system to help forest governance in Madagascar to deal with the challenges you mentioned?

An Independent Forest Monitoring program, as pioneered in places like Cambodia, Honduras, Nicaragua or Cameroon, can be a valuable tool in increasing transparency and accountability. What IFM can introduce is an impartial and credible voice with the right to access and analyze official information and to make this information publicly available. In various countries where EIA has worked, everyone acknowledges illegal logging to be a serious problem, but actual evidence is scarce as local organizations or officials feel it's too risky or pointless to combat powerful economic forces or institutional corruption. EIA's going undercover and documenting clear evidence, bringing it to the light of day, creates new political space for change. IFM does the same but with official sanction, much like the GW/EIA report did last year. If there is government buy-in for IFM, it becomes very difficult to deny or refute the results of this monitoring.

Now obviously, acknowledging governance failures is not the same as doing anything about them. If the political will does not exist to tackle forest sector problems – because, for example, state revenues are dependent on 'fines' paid by exporters to allow illegal wood to leave the country – then IFM is going to be limited in its ability to transform governance. In the long term, however, I do think these programs lead to a gradual increase in the expectations of accountability. In Honduras the IFM program has seen, over the four years it's been operating, increasing rates of follow-up on its recommendations by various government enforcement offices and the forest authority.

Who would you like to see participating in such an IFM and how could it be funded?

IFM requires a lot of legwork at the beginning if it's going to have a chance of success. There must be a host institution with enough trust in both the concept and the actual team of monitors. This institution might be the MEF (Ministry of Environment and Forests) itself, it might be ONESF, it might be MNP (Madagascar National Parks) depending on the scope of the IFM. Then, there must be at least some buy-in from other forest stakeholders, like logging companies, parks and tourism officials, customs or finance officials. And there must be a real funding commitment from an outside independent source. I would think that the search for funding would begin, in Madagascar's case, in the CCPFT Roundtable (*Cercle de Concertation des Partenaire Financiers et Technique du MEF*).

However, another recent development that needs to be explored is the forest-carbon funding streams under the rubric of Reducing Emissions from Deforestation and Degradation (REDD). REDD financing could go in part to independent monitoring; REDD also provides compelling new possibilities for placing value on Madagascar's forests. But effective REDD will depend on our achieving a new standard of monitoring and transparency in forest management, and on truly cutting down on the corruption in this sector. Is the Madagascar government looking to pocket REDD funds from the international community on the one hand, while continuing to authorize illegal timber exports? Are NGOs and donors watching this happen?

ETIENNE RASARELY

Please introduce yourself briefly – how are you related with Madagascar's forests? In your opinion, why are forests important?

Je suis Etienne Rasarely, forestier et manager de formation, ayant par ailleurs un intérêt marqué pour tous sujets en rapport avec l'économie et les relations internationales. Je travaille pour le compte de l'Observatoire National de l'Environnement et du Secteur Forestier (ONESF), et en assure depuis 2003 la Coordination nationale. Concernant l'ONESF, celui-ci a été mis en place, suite aux résultats mitigés de l'évaluation à miparcours du Programme Environnemental malgache dans les années 2000. Il a été chargé de suivre et rendre compte de l'avancement du processus d'amélioration de la Gouvernance du secteur, reconnue comme un des problèmes majeurs ayant réduit l'efficacité du programme.

Le champ d'observation de l 'ONESF s'étend sur l'ensemble du pays, et couvre le fonctionnement et le respect des lois qui gouvernent le secteur, compris comme un système, incluant administration, opérateurs, organismes d'appui... Il s'intéresse, aussi bien au processus de création et d'évolution des forêts, qu'au maintien de l'intégralité de leurs différentes fonctions ; mais aussi à l'utilisation rationnelle et durable des ressources forestières, pour le bien être et la satisfaction des différents besoins économiques et sociaux de la population. Les objets d'observation de l'ONESF gravitent notamment autour de (i) l'exploitation forestière, (ii) la mise en œuvre de la convention CITES, ratifiée par Madagascar; (iii) le fonctionnement du système de transfert de gestion, orienté vers une gestion de proximité des forêts par les communautés de base.

A votre question sur l'importance des forêts, voici ma réponse de forestier! Un monde dénudé, où dominent béton, plastic et macadam, noyé sous les différentes pollutions de l'atmosphère, des eaux, des sols et inondé de bruits, reste-t-il agréable à vivre ? Le rôle vital des forêts et leur effet tampon dans le maintien de l'équilibre climatique global, ainsi que du cycle bio-géo-chimique de la planète, est démontré. La « santé globale » de la planète en dépend. Réserve de gènes et vaste champ ouvert à la recherche de molécules intéressant l'industrie pharmaceutique et la médecine, la capacité des forêts à absorber les gaz à effet de serre, contrecoups de la croissance démesurée des pays industrialisés, est aujourd'hui évaluée et échangée sur le marché, dans le but de stimuler le reboisement, ou d'éviter la déforestation dans les pays en développement. L'absence de forêts dans certaines parties du globe se fait déjà ressentir de manière cruciale. A Madagascar, particulièrement, la forêt est réserve de terres, de nourriture, de matériaux de construction, de médicaments, de loisirs... Le père de famille que je suis recommande à ses enfants d'aimer la forêt et d'en prendre bien soin.

Where do you see current and future challenges in managing and conserving Madagascar's forests?

Je répondrai à cette question en passant en revue les différents enjeux auxquels le pays doit faire face. Je citerai la nécessité (i) en premier lieu et à très court terme de démanteler le réseau actuel de pillage organisé de nos ressources en bois précieux, protégé et entretenu par la corruption. (ii) Résoudre l'impasse de l'impunité, par une application stricte de la loi et des textes forestiers, à travers un traitement convenable des contentieux forestiers, les dossiers bien ficelés au niveau de l'administration forestière (élimination des différents motifs de rejet: manque de charges, vice de fond, vice de forme, vice de procédure), devant être instruits convenablement au niveau d'un Tribunal, doté d'une connaissance appropriée des textes forestiers ; (iii), Réinstaurer une administration forestière crédible, efficace et intègre, soutenue par un corps forestier réconcilié avec son éthique et sa déontologie, assumant sa responsabilité de gestionnaire de patrimoine (efficacité du contrôle, effectivité du système de traçabilité...) (iv) Consolider à la base les acquis de ce processus de réforme et d'assainissement, par la formation et la valorisation des différents corps de métiers liés à la gestion des forêts, au profit d'une amélioration obligatoire des structures de gestion et de leur fonctionnement. (v) Désamorcer le spectre de la crise du bois qui, dans un avenir proche, risque de se réaliser, sans augmentation, renouvellement et maintien d'un capital forestier suffisant, pour absorber les différents besoins actuels et futurs en bois (énergie, construction...). (vi) Promouvoir le partage de responsabilité et la synergie d'action entre une Société Civile structurée et les communautés riveraines, gestionnaires de proximité auxquels reviendra à terme la fonction d'observation, moyennant renforcement de leurs capacités de négociation et réhabilitation de leur dignité, à travers une solution radicale à la problématique de la pauvreté (nourriture, santé, éducation...). (vii) Cet environnement sain permettra aux opérateurs du secteur de développer leurs activités durablement avec efficacité.

What do you think of an Independent Forest Monitoring (IFM) system to help forest governance in Madagascar to deal with the challenges you mentioned?

Pour corriger tout système déréglé, un recul suffisant est indispensable et un regard sur l'ensemble, nécessaire pour détecter objectivement les défaillances. Menée de l'intérieur même du système, une telle entreprise s'avère plutôt aléatoire. Pour assainir et remettre en route la gestion forestière, l'intervention d'un tiers extérieur au système peut s'avérer pertinent.La mise en place de l'ONESF fut déjà un pas dans ce sens, dans la mesure où de façon indépendante, selon son statut et les normes qui lui sont propres, l'ONESF collecte des informations objectives, analyse le degré d'illégalité des faits et observe les failles du système de contrôle. Au constat des faits à tendance perverse, il interpelle les responsables concernés et s'implique jusqu'à mobiliser / dynamiser des actions concrètes et appropriées, pour corriger les anomalies décelées.

Conjointement avec d'autres entités du système national d'intégrité (BIANCO, forces de l'ordre, douanes, unité de contrôle de l'administration forestière), l'ONESF est également intervenu dans des missions de contrôle ou d'assainissement. Les rapports indépendants de l'ONESF n'ont cependant pas tous été rendus publics, mais étaient uniquement destinés aux hauts décideurs, ainsi qu'aux organismes de financement. L'opérationnalité et l'efficacité de la structure, dotée des ressources humaines, matérielles, techniques, financières suffisantes, doivent être consolidées, à travers l'amélioration du cadre juridique, qui doit lui garantir explicitement le principe d'indépendance, l'accès à l'information et la libre publication de ses résultats.

Dans le court terme, l'ONESF est favorable à l'ouverture au partenariat avec un observatoire indépendant international. Mais comme il s'agit d'une crise minant en profondeur les structures socioéconomiques du pays, il faut veiller à l'enracinement local du processus, les communautés locales devant à terme s'en approprier pour devenir la principale partie prenante de la gouvernance forestière. Aussi, le partenariat doit surtout permettre l'engagement réel des entités nationales et aboutir au renforcement des acquis pour assurer la pérennisation. Une volonté politique au plus haut niveau demeure toutefois à la base d'une implantation réelle, et cautionne la synergie des actions et la réussite même de tout le processus. Un réel équilibre entre les pouvoirs exécutif, législatif et judiciaire s'avère nécessaire, pour rendre effectif un mécanisme de contrôle mutuel efficace et profitable à tout le dispositif.

Who would you like to see participating in such an IFM and how could it be funded?

Ce partenariat, pour être efficace et pérenne, doit veiller à la constitution d'un véritable réseau, dans lequel la participation et la prise de responsabilité seront élargies progressivement, au fur et à mesure de l'acquisition du savoir faire nécessaire. Le rôle de starter-accompagnateur exercé initialement par le tandem ONESF-Observatoire indépendant international sera élargi aux organisations de la société civile. Une définition précise du rôle et des responsabilités revenant à chaque catégorie d'acteurs (CTD, Communes, Régions, Fokontany, VOI…) s'impose. Présents jusqu'au niveau local, les organismes d'appui vont relayer les informations. A terme, tous se verront intégrés dans le processus.

Au sujet du financement, l'intérêt mondial à pérenniser les forêts se traduit concrètement dans l'appui des bailleurs de fonds à plusieurs initiatives connexes. Le mécanisme REDD peut entre autres être étendu au processus. Mais le profit généré par le système en faveur des différents bénéficiaires étatiques et du secteur privé doit à terme motiver les parties à contribuer à son financement.

CHRISTIAN BURREN

Please introduce yourself briefly – how are you related with Madagascar's forests? In your opinion, why are forests important?

I am a forest engineer from Switzerland and have been involved in forest management in Madagascar for about 20 years on different levels. For the last ten years I have been working in Madagascar with NGOs and for Development organisations supporting local communities, private operators and the forest administration to make forest management more sustainable and use of forest products more efficient. I am now working for the Wildlife Conservation Society in Brazzaville, Congo.

Like in many other tropical countries, rural people in Madagascar depend strongly on timber and non-timber forest products for their livelihoods. This is most apparent in the energy sector, with firewood and charcoal covering more than 80 % of the national energy needs. This results in relatively high wood consumption on a national level (22 million m^3 per year) that has to be covered by national timber production. In addition, forests provide important ecosystem services such as biodiversity conservation, watershed protection and others, and they are also considered by local populations as future agricultural land reserves.

Where do you see current and future challenges in managing and conserving Madagascar's forests?

Conservation of forests must include forest protection, sustainable management and restoration (reforestation) of degraded forests. Since all natural and many artificial forests belong to the state, these activities theoretically have to be carried out by the forest administration entity. However, in practice, the forest administration has neither the means nor the capacity to do so.

Therefore, improving forest governance is essential. This could involve the integration of locals and other actors (e.g., private operators) into forest management, requiring the continuation of current efforts to transfer forest management to local communities as well as to private professional operators. On the other hand, a deep reform of the forest administration is needed in order for them to provide sufficient support to new forest managers. An important aspect in this context is increasing the productivity of the techniques used to transform forest products, especially charcoal.

Forests have to compete with other land uses like agriculture, mining and infrastructure development. We have to make sustainable use of forest resources more competitive compared to other land uses, especially agriculture. This could be achieved by maximizing benefits from sustainable forest management to local people, including the efficient harvesting and transformation of forest products, as well as payments from ecosystem services (carbon sequestration, biodiversity conservation, water, etc.) and ecotourism.

What do you think of an Independent Forest Monitoring (IFM) system to help forest governance in Madagascar to deal with the challenges you mentioned?

There is no doubt that insufficient monitoring of forests and of forest management is a major issue in Madagascar. In order to manage forests in a sustainable and efficient way, managers need information regarding the impact of forest management and other activities on the forest ecosystem.

Currently, however, forests are managed and exploited in an inefficient and non-sustainable manner. A forest monitoring system might not be the most important thing and would be primarily limited to providing a general overview of the state and the extent of natural and artificial forests. An IFM could probably guide political decisions on forest management and conservation.

Besides this more national-level forest monitoring, more specific forest monitoring on sites with well established management systems, such as management transfers, could be important for demonstrating the potential of sustainable forest management and substantial income benefits to local communities. This might provide a case for the forest administration to improve support for such systems.

Who would you like to see participating in such an IFM and how could it be funded?

A forest and forest management monitoring system should be independent from forest managers themselves in order to reduce the risk for conflicts of interest. This is very difficult as almost everybody is currently involved in forest management in some way or another.

I firmly believe that the state should play a major role in monitoring forests and forest management activities. However, this can only be efficient and 'independent' if the forest administration retires from direct management of forests and transforms itself into a real forest 'service' providing support to the forest managers (reinforcing their technical, organisational and commercial capacities) and monitors their activities and impact on forest ecosystems in order to improve sustainability and efficiency of forest management.

DOREEN ROBINSON

Please introduce yourself briefly – how are you related with Madagascar's forests? In your opinion, why are forests important?

Since 2003, as an employee of the United States Agency for International Development, I have worked to support the sustainable management and conservation of Madagascar's rich forests. In 2008 I took over as the Director of the Office on Environment, Rural Development and Food Security for USAID in Madagascar. Working with my team, partners and the government of Madagascar, I was optimistic that gains in forest management and biodiversity protection that we made over two decades of partnership were helping to realize a vision of a healthy, sustainable environment that would benefit the Malagasy people. Unfortunately, the political events since 2009 have dampened my optimism. In early 2010, as a result of Madagascar's undemocratic and unconstitutional change of power, the US government suspended all but humanitarian programs, and I was relocated to South Africa as a Regional Advisor for Biodiversity, Natural Resources Management and Climate Change. I monitor the situation in Madagascar closely, continue to engage in dialogues and anxiously await a time when the US government can relaunch its environmental support. But the time is short. What we have witnessed in Madagascar's forests over the past year has been devastating. Unscrupulous behavior and a general breakdown in systems and rule of law have led to an open access situation, where a select few seem to get the majority of the benefit. The greater good of the Malagasy people as a whole, the resiliency of the island's natural resource base and the ability to recover from the economic effects of this crisis have all been severely undermined by rampant environmental destruction. Some folks have said to me, "if they lose a few species of trees, what is the big deal?" But those trees are part of an ecological system that keeps the soil on steep hillsides, provides homes to wonderfully unique wildlife and plants, retains water and regulates local weather. Those trees are part of a social system, a cultural identity and way of life that Malagasy people have practiced for generations. Those trees are part of an economic system providing timber and non-timber forest products bringing income into the homes of Malagasy families and generating dollars and euros from tourists wanting to pay to see an important piece of the world's natural heritage. As these systems start to fall apart, more people will suffer.

Where do you see current and future challenges in managing and conserving Madagascar's forests?

Personally, the largest problem I see right now is the lack of political will within the Government of Madagascar. A courageous vision is needed to put in place a system where a majority, not a minority, benefits from Madagascar's forests and their biodiversity. Policies and decrees are important, but only if they are backed up with committed action. Otherwise they are not worth much more than the price of the paper that they are printed on. While I believe there are capacity issues in Madagascar, many of the tools for sustainable forest management and conservation are available in Madagascar. The US government, other donors, international organizations and most importantly, Malagasy civil servants, communities and civil society organizations have helped to develop them. Chain of custody, enforcement, human resources management, forest monitoring, and sustainable harvesting plans have been developed, tested and employed. While we need to improve and expand these tools, the foundations are there. Another great challenge is having the right systems in place to ensure that the communities most dependent on the forests receive the benefits from the forests in transparent and equitable ways. I recently saw men heading into the forests near Masoala National Park to cut down some rosewood so they could get money to buy rice. They thought they would get enough money to cover their needs for about a month. I know what those trees are worth on the international market, and it is really sad that all they will get is a month's worth of rice. What will they do when the rosewoods are gone? That time may not be far off. And these three men don't have as many options as other people further up the value chain who are certainly getting more than a sack of rice. The deterioration of Madagascar's forests is unfortunately not a new problem; it is just that it has gotten worse. We need to change the system to create the right incentives to promote behavior that is sustainable for Madagascar's forests.

What do you think of an Independent Forest Monitoring (IFM) system to help forest governance in Madagascar to deal with the challenges you mentioned?

I think independent, third party monitoring has value. There is certainly a need for better data regarding exactly what is going on in Madagascar's forests. The data is not so easily verifiable, particularly since the political crisis began. IFM can also help bridge the capacity gap for forest monitoring. IFM also offers a way to root out and exposure corruption in the system. But in then end, IFM can only do so much. The state is still responsible for enforcement. The state is still responsible for ensuring money obtained from fines collected will be invested back into the forestry sector in a wise way. Otherwise, the collection of fines can become an appealing way to make money in a cash-strapped government. In the end we come full circle to my initial point about political will. Any proposal for IFM needs to be considered in this broader context.

Who would you like to see participating in such an IFM and how could it be funded?

There is a lot of international expertise on tropical forest monitoring out there – it is important to tap into that expertise and bring it to Madagascar to nurture in-country skills. I think it is possible to maintain the independence of IFM while also transferring local skill and capacity within Madagascar. I personally know some amazingly committed, bright and capable forest experts in Madagascar working in civil society, I would want to see such individuals at the core of any initiative. I also think some creative partnerships could be developed with local communities to build their awareness, but also to empower them in their own stewardship of their forests. My model of a functioning, thriving society is one that is both willing and capable to demand accountability from its state. If civil society is not built in from the beginning, we will not see the kind of changes we need to see in the Malagasy forestry sector. Funding could come from a variety of international sources to initiate. The private sector has a stake in securing a healthy forest future for Madagascar, and they should also be tapped for support.

The views or opinions of the author do not necessarily represent the views of the US Agency for International Development or the US Government.

MARTIN BAUERT

Please introduce yourself briefly – how are you related with Madagascar's forests? In your opinion, why are forests important?

I am a biologist and focused my doctoral and postdoctoral research on the population biology and genetics of relict arctic and alpine plant species in the Alps and the Scandinavian Arctic. I am a curator at the Zurich Zoo and responsible for the Masoala Rainforest Ecosystem exhibit as well as the follow up of the in-situ conservation projects, which are supported by the Zurich Zoo.

The Masoala Rainforest Ecosystem is a giant 11,000m^2 greenhouse acting as a microcosm to promote the conservation of rainforests in general and specifically of the Masoala National Park which is located on the east coast of Madagascar. In 1996, the Zurich Zoo established a Memorandum of Understanding (MOU) with the Malagasy Ministry of Environments and Forests to raise awareness of rainforest conservation in Madagascar as well as in Switzerland. The MOU regulates access and benefit sharing between the Masoala National Park and Zurich Zoo according to the Convention on Biological Diversity (CBD) and facilitates research collaborations. The Zurich Zoo provides about 25 % of the running cost of the Masoala National Park and finances multiple bottom-up micro development projects in its surroundings.

Forests are crucial for the long-term stability of almost any human society. The ecosystem services that forests provide, such as soil erosion control, watershed security, net primary production, water transpiration, and the sustainable production of timber as well as non timber forest products are so essential that the loss of forest is very often linked to the disappearance of the human society that eradicated them. Jared Diamond describes many such examples in his book COLLAPSE, covering more than 3,000 years of development and disappearance of distinct human societies.

Where do you see current and future challenges in managing and conserving Madagascar's forests?

The forests in Madagascar are dwindling because charcoal still is the primary source of energy for cooking for the majority of the population and because of slash and burn agriculture which destroys once productive soils at an alarming rate. The often illegal harvesting of precious woods like ebony and rosewood is, to a lesser extent, also triggering forest degradation. The systematic felling of the most valuable hardwood timber not only depletes the forests of the most storm resistant trees but also requires significant amounts of less-dense tree species for flotation assistance during river transport. Often the extraction of precious woods also opens trails and access routes to once pristine forest and reduces mammal abundance through the associated hunting of bush meat.

The present challenges for improving forest conservation in Madagascar are the provision of affordable cooking energy to the population, independent of primary forests; the advancement of sustainable agricultural practices and methods of soil protection; and better forest governance in the timber sector.

What do you think of an Independent Forest Monitoring (IFM) system to help forest governance in Madagascar to deal with the challenges you mentioned?

An Independent Forest Monitoring system, which is agreed on by the relevant governmental authorities and covers all remaining forests would in my view be crucial to assess legal compliance of local timber production and to enforce the forest law that is basically well developed in Madagascar.

Who would you like to see participating in such an IFM and how could it be funded?

The organisation commissioned with the IFM must be carefully evaluated for its independence, credibility and objectivity. The implementation of IFM could be facilitated by international donors and organisations, which are involved in setting up good governance and trustworthy administrative systems. In the long run, IFM, a tool to produce legal and sustainable timber, should be regarded as part of the normal production cost of timber, and its expenses should be reimbursed by the timber sector. If such a refund by the timber industry is to establish, the genuine independence of the IFM provider must be very carefully observed.

JEAN-PIERRE SORG

Please introduce yourself briefly - how are you related with Madagascar's forests? In your opinion, why are forests important?

I graduated in Forest Sciences at the Swiss Federal Institute of Technology Zurich (ETH Zurich) and obtained my doctorate with a thesis on subalpine spruce forests in 1977. From 1977 to 1986 I worked for the Swiss Agency for Development and Cooperation (SDC) and for Intercooperation as a scientist and project manager in projects in Rwanda (ecology and management of mountain forests, afforestation, agroforestry) and Madagascar (ecology and management including reduced impact logging in dense dry forests, silviculture and related research). Since 1986, I have been a lecturer in international forestry and agroforestry at the Department of Forest Sciences at the ETH (now Department of Environmental Sciences). I am the head of the Groupe de foresterie pour le développement (GFD). I spent five years in Madagascar as a project manager at the Centre de Formation Professionnelle Forestière Morondava (CFPF, today CNFEREF). My particular interests were the ecology of dry forests as well as silvicultural questions. Since then I have taken part in and led various research projects in the region. At the department Eaux et Forêts of the Ecole Supérieure des Sciences Agronomiques (ESSA), I was significantly involved in educating students.

Forests are one of the most important hosts of biodiversity worldwide. Furthermore, forests provide habitat and basic food resources for tribal communities and provide goods and services for a wide range of populations living near in close proximity to or far from forests. Forests also help regulate the global climate.

Where do you see current and future challenges in managing and conserving Madagascar's forests?

Due to the immense poverty on the island, the overexploitation of natural resources and the traditional 'slash-and-burn' farming, where forests are cut down and set ablaze to clear land for planting subsistence crops and for animal husbandry, is the most urgent challenge.

What do you think of an Independent Forest Monitoring (IFM) system to help forest governance in Madagascar to deal with the challenges you mentioned?

An IFM could certainly provide good services and is worth of support. However, this leads to a second question, is it more appropriate to assist the Forest Services in the field and provide them with the means to better fulfil their functions? Moreover, it would be vital to improve agricultural yields to tackle poverty, in order to get down the root of the problem. Under no circumstances should an IFM become a repressive tool as this would only cause harm.

Who would you like to see participating in such an IFM and how could it be funded?

In my opinion, neither foresters nor conservationists should have the majority of members in an IFM program, and it is also important that indigenous people have the leading role. I imagine that farmers could play a positive role in this body as well. The Center of International Forestry Research (CIFOR) could also be a potential participant.

MADAGASCAR FAUNA GROUP

Please introduce yourself briefly -- how are you related with Madagascar's forests? In your opinion, why are forests important?

Madagascar Fauna Group (MFG) is an NGO that has been working in Madagascar for 22 years. Based out of Toamasina on the east coast, MFG manages Parc Ivoloina: An eco-tourism site that originally began as a simple zoo set within a forestry station but has evolved into a multi-disciplinary conservation and training centre focusing on key issues ranging from improving agricultural sustainability to environmental education and professional training initiatives. MFG is also Madagascar National Parks' (MNP) formally recognized research partner for Betampona Natural Reserve, 40 km northwest of Toamasina for 20 years. Betampona represents one of the last remaining eastern lowland rainforests in Madagascar and is of vital conservation importance in terms of its faunal and floral biodiversity, including a number of site-specific endemics. We carry out research of direct conservation-management significance such as for example research on invasive plants, primary forest cover changes, and bushmeat consumption. MFG works closely with MNP and the local people to help protect Betampona's forest directly through the organisation of regular surveillance patrols, environmental education initiatives and providing eco-agriculture training to demonstrate practical alternatives to traditional *tavy* ('slash and burn') practices. MFG has also established a forest restoration project in association with MNP by installing plant nurseries around Betampona, and provide the tree seedlings of native plant species free of charge to local farmers to reforest areas within Betampona's 'Zone of Protection' and surrounding areas. The aim is to create a buffer zone to protect the Reserve from forest degradation.

Multiple publications and studies have highlighted forests' importance and the ecosystem services they provide as in stabilizing soils, regulating climates, protecting watersheds, functioning as carbon sinks, filtering water and air and harbouring many pollinators and seed dispersers of key fruit species and crops, and so on…

Where do you see current and future challenges in managing and conserving Madagascar's forests?

As E.O. Wilson wrote "Destroying rainforest for economic gain is like burning a Renaissance painting to cook a meal." In Madagascar much of the forest is cut literally with the intention of "cooking a meal". The majority of the population relies on locally collected wood for cooking and construction purposes. However, the leading cause of forest-loss is the practice of *tavy* which is why one of the biggest challenges facing conservationists and land managers in Madagascar today is the need to respectfully modify traditional farming practices that have been revered for centuries and, indeed, millennia. A new paradigm holds great promise that, through a high level of collaboration and communication by specialists in different disciplines, it is not only possible but beneficial to develop land management practices in which agriculture and biodiversity co-exist. Referred to as eco-agriculture to accentuate its core belief, this new approach recognizes that both increasing agricultural production for human consumption and income generation and conserving biodiversity and ecosystem services are equally important and vital objectives to maintain the health of our planet. Within this holistic landscape natural resource management system, logging would also be subject to best-practice principles. To prevent the current uncontrolled and massive illegal felling of precious woods, logging operations would need to be effectively monitored while existing or new legislation would need to be enforced in a systematic and transparent manner.

What do you think of an Independent Forest Monitoring (IFM) system to help forest governance in Madagascar to deal with the challenges you mentioned?

First of all, such a body would be invaluable as long as it had sufficient funds and power to carry out its specified objectives. Much of Madagascar's remaining forest is in highly inaccessible areas so a substantial budget and work force would be necessary to effectively monitor the real situation on the ground. We believe that in large part current protection efforts fail due to the lack of sufficient well-trained and motivated personnel in the field. Transparency, objectivity and independence from both government bodies and logging operators would be vital prerequisites for the success of an IFM. Secondly, an IFM can only realise its objectives in a climate where there is actually the political will to recognize the current deforestation problems, the commitment to react accordingly and enforce longstanding existing laws and follow independent recommendations as put forward by an IFM. Finally, we feel that an IFM needs to be one component of a diversified approach in order to ensure a successful programme to control the rate of deforestation in Madagascar. Efforts to promote sustainable forestry and improved eco-agricultural practices must be redoubled as only through providing realistic alternatives to *tavy*, firewood, charcoal and unsustainable logging can the current rate of deforestation be slowed.

Who would you like to see participating in such an IFM and how could it be funded?

To be truly independent the IFM should consist of an international body or consortium that work at the invitation of the Malagasy government but, critically, remain independent of them. Some of the international and national NGOs, which already operate and have a strong conservation commitment in Madagascar, would be ideal candidates to act as a committee of advisors as well as 'watchdogs'. A balanced mix of international and Malagasy groups would be ideal to ensure objectivity and vitally important local knowledge. Support for setting up an IFM could be sought from sources such as the GEF, FAO, UNDP, EU as well as World Bank which all have ongoing international programs addressing deforestation or REDD issues, In the long run, a reasonable 'conservation tax' could be levied from tourists, which directly funds IFM activities. Through REDD, carbon markets could provide funding as well as part of the monitoring and evaluation of projects at local and national level.

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

IZAHO MAHITA IO SARY IO, MITENY HO AZY AO AM-POKO SI NY FANAHIKO NY MAHITA AZY
Bakary Sabbir Patrick, Toliara
(Quand je vois cette photo, elle me va droit au cœur et à l'âme)
(When I see this photo, I feel it in my heart and in my soul)

MISOKATRA AMIN'NY FIAINANA NY MASONY OMBAIN'NY FIAROVAN'NY RAIAMANDRENINY AZY (ILAY RAMBO).
Malala Razafimpahanana, Antananarivo
(De grands yeux ouverts vers l'avenir avec la protection constante des parents – par la queue –)

LES GRANDS YEUX DU LEMURIEN !
Yohann Camara
(un petit garçon de presque 3 ans de qui on dit qu'il a les grands yeux !)

TAHAKA NY OLOMBELONA, OHATRA NY MIFANKATIA IZAREO
Rainandimby Fernand Daniel, Toliara
(Ça ressemble à une personne, ils semblent s'aimer)
(It looks like a person, they seem to love each other)

NA DIA EFA MAHAZATRA AZA NY MAHITA NY SARIN'NY MAKI DIA MAMPAHATSIAHY AHY FOANA NY MAHATOKANA NY HAREN'NY TANINDRAZAKO.
Marie Jeanne Raherilalao, Antananarivo
(Voir un maki commence à être habituel, mais à chaque fois cela me rappelle l'unicité de la richesse de mon pays)

TSY MISALASALA ILAIKELY MIBANJINA NY MPAKA SARY AZY SATRIA MATOKY MANANA IRETO LEHIBE.
Voahangy Soarimalala, Antananarivo
(Le petit n'a aucune crainte devant l'objectif car la présence des grands le rassure)

NY GIDRO SY NY BIBY MITOVITOVY ENDRIKA TSY MISY HAFA TSY ETO MADAGASIKARA IRERY IHANY, NOHO IZANY DIA TSARA ANY HITEHIRESANA IREO.
Razakason Ernest, Toliara
(Les lémuriens et d'autres animaux n'existent nulle part ailleurs qu'à Madagascar et nous devrions nous en occuper)
(Lemurs and similar animals don't exist anywhere else but Madagascar, and so we should look after them)

TOKONY AROVANA NY ZAVA-MANAN'AINA MBA TSY HO LANY TARANAKA.
Françoise Ramalalatiana, Antananarivo
(La biodiversité devrait être protégée pour qu'elle ne disparaisse à jamais)

TOKONY HOHAJAINA SY KOLOKOLOINA TSARA IZY IREO
Miran-DRainy Mahavonjy, Lycée Antananarenina, Toliara
(Nous devrions les respecter et les protéger)
(They should be respected and should be well looked after)

TOKONY AROVANA NY TONTOLO IAINAN'NY MAKY
Rafidison Handimby, Lycée Antananarenina, Toliara
(Nous devrions protéger l'environnement des Maki catta)
(We should protect their environment)

NY MAKY MAMPIAVAKA AN'I MADAGASIKARA AMIN'NY FIRENENA HAFA
Ananiasy Gaëtan Hilaire, Lycée Antananarenina, Toliara
(Ce sont les Makis catta qui font que Madagascar est différent des autres pays)

IMPRESSUM

Madagascar Conservation & Development is the journal of Madagascar Wildlife Conservation (MWC) and the Jane Goodall Institute (JGI Switzerland). It is produced under the responsibility of these institutions. The views expressed in contributions to MCD are solely those of the authors and not those of the journal editors or the publishers.

COVER PICTURE: *Lemur catta* family by Roland & Julia Seitre [France]

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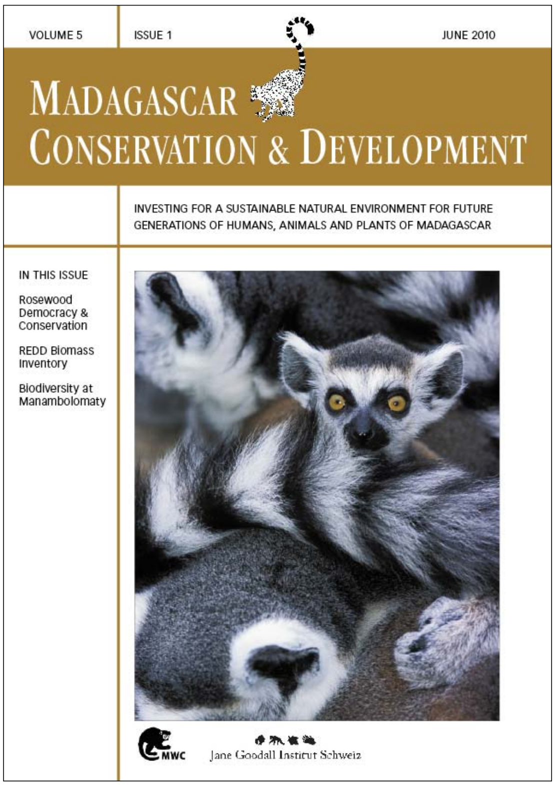

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