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MADAGASCAR CONSERVATION & DEVELOPMENT

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

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EDITORIAL

Madagascar – the only certainty is change

The political situation witnessed in Madagascar since the beginning of this year has resulted in major changes in the daily lives of the Malagasy. Besides instability and increased uncertainty, the population is facing more imminent challenges: increasing unemployment, exploding staple food prices, a shortage in basic food supplies, and a closure of schools, universities and financial institutions. How will Madagascar be affected in the near and long term? This remains unknown, however, it is highly probable that the current situation will negatively affect all levels of Malagasy society. These impacts are likely to be longer lasting and more far-reaching than currently anticipated.

In this issue, Doreen Robinson from USAID is presenting three ecological concepts in her foreword "A changing Madagascar": connectedness, resiliency and reconciliation. These are consistent with Buzz Holling's theory of *adaptive cycling*. Imagine Madagascar is traveling on a trajectory in the form of a figure of eight laid on its side attached to this text, or an infinity symbol in 3-D. On the front loop (the right side in the figure) there is the 'K'-phase where a system, such as a forest or society, is becoming increasingly established and conservative and reaches a point of 'over'-stability, which risks becoming too rigid. With low resilience, it becomes increasingly prone to external forces. If such forces succeed to cause the system to collapse and chaos prevails in the 'Ω'-phase, the result is the release of the old system and its energy. This release, however, can trigger a new beginning. In the 'α'-phase of reorganization and renewal, a new system emerges. In the 'r'-phase swift exploitation and growth are occurring and the more time passes, the more the processes slow and the conservative 'K'-phase approaches. During this growth period, several processes are simultaneously at work. The potential for novelty, innovation and wealth increases, as does the connectedness and reconciliation of the system components. Meanwhile, the overall resiliency of the system decreases, that is, the system becomes rigid once more.

There are rumors that the current political turmoil has been curbed by a 'land deal' with a South Korean company. In a country like Madagascar, where traditional land-use and strong beliefs in ancestry are prevalent, such news might have caused a cultural shock and a resultant backlash. However, as discussed in an essay by Geoffrey York from the International Food Policy and Research Institute in March 2009, claims to land in developing countries by developed countries might become more common in the near future as they face ever-dwindling land area coupled with increased demands for resources. For governments of developing countries, with an abundance of cheap land, they might find quick 'land-deals' simply too tempting. The same can be said for resources below ground. Natural resources are shifting ever more to the center of attention, and as Johny Rabenantoandro from QMM/RioTinto aptly emphasises in the other foreword of this issue, we need to start appreciating the richness of biodiversity and safeguarding it for the future in order for our children to enjoy it. Pertinent

questions arise in this context: how will we deal with social, environmental and economic changes; how can changes in resource availability, or in demand for such resources, be absorbed by our existing ecological and societal systems without precipitating collapse?

Our questioning of the fate of Madagascar's future does not end here. Fortunately, we are presented with the opportunity in this issue to make contributions that can explore these very questions. In the newly introduced journal section SPOTLIGHTS, Jeffrey Sayer (IUCN) argues for the landscape mosaic as the solution to reconcile conservation and development. In another contribution, William McConnell from Michigan State University reviews modeling human agency. Modeling is an emergent topic in Madagascar as it is elsewhere, and it can be a helpful tool to gain a greater understanding of land-use patterns, which is pertinent to the study of livelihoods and other socially-based research. Another contribution draws on interview-based research to understand the livelihood needs of fishermen and rice cultivators of the Alaotra marshes. How can the conservation of biodiversity and livelihood needs be balanced? How can rare and endangered species and their ecosystems be protected without compromising people's basic needs to survive? To answer such pressing questions, we need to substantially expand our knowledge base by gaining more insight into the ecological systems within which conservation and development exist. The authors of two other contributions on lemurs and birds help to expand such a knowledge base.

In summary, although these times of change and upheaval are overturning seemingly stable systems, there is also hope that the release of energy we are currently experiencing in Madagascar will develop into a 'Holling's loop' where new opportunities can be formed. We should take this momentum to free even more energy and funnel it into research, so we can enlarge our knowledge base, increase our understanding of the interconnected systems and enforce our resilience in order better to adapt our readiness to future changes. For the only certainty we have for Madagascar's future is change.

Patrick O. Waeber, Founder Editor
Lucienne Wilmé, Editor-in-Chief

Seule certitude à Madagascar : le changement

Depuis le début de l'année, nous sommes témoins d'une crise politique à Madagascar qui a profondément changé le quotidien de bon nombre de gens. En plus de l'insécurité et de l'instabilité, la population se retrouve à faire face à de nouvelles situations avec une augmentation du chômage, l'explosion des prix des produits de première nécessité, des pénuries dans les approvisionnements, la fermeture d'écoles, d'universités ou d'institutions financières. Pour l'avenir, on peut se demander dans quelle mesure Madagascar resterait affectée par ces événements mais sans rentrer dans une polémique ni nous lancer dans des pronostiques, il semble vraisemblable que l'ensemble de la société malgache sera touchée et dans des proportions plus graves que ce qu'on pourrait imaginer.

Dans ce numéro, Doreen Robinson de l'USAID présente trois concepts écologiques dans sa préface « Réflexions sur Madagascar, pays en évolution » qui sont la connexité (ou connectance), la résilience et le rapprochement. Ces termes sont empruntés au cycle adaptatif de Buzz Holling. Imaginez Madagascar se déplaçant sur une trajectoire en forme de huit couché ou représenté par le symbole de l'infini dans l'espace. Sur la boucle du premier plan (à droite sur le dessin) nous avons une phase K au cours de laquelle un système, qui peut être une forêt ou une société, se stabilise, s'établit et en devient conservateur jusqu'à atteindre un point où il est tellement stable qu'il en devient rigide. Avec une faible résilience, un tel système devient vulnérable face à des perturbations extérieures et si de telles perturbations devaient s'appliquer et entraîner l'effondrement du système, on rentrerait dans une phase 'Ω' avec une libération de l'ancien système et de son énergie. Cette libération peut cependant déclencher un renouvellement, dans la phase 'α' de réorganisation et de renouveau, un nouveau système émerge. On assiste dans la phase 'r' à une croissance et une exploitation rapides et plus le temps passe et plus le système ralentit pour se rapprocher de la phase 'K'. Au cours de cette période de croissance, on assiste à plusieurs processus qui ont cours en même temps avec un accroissement des changements, des innovations et de la prospérité en même temps que les composantes du système gagnent en connexité et en rapprochement. Simultanément, la résilience globale du système baisse de sorte que le système devient rigide, une fois de plus.

Certains disent que le contrat de cession de terres à une compagnie sud-coréenne aurait déclenché la crise politique de 2009. Dans un pays tel que Madagascar où l'utilisation traditionnelle des terres et l'attachement aux ancêtres est de règle, de telles annonces pourraient déclencher un choc culturel et un retour de manivelle. Cependant, comme le disait Geoffrey York de l'International Food Policy and Research Institute dans un essai publié en mars 2009, les revendications de terres dans les pays en voie de développement par les pays développés pourraient devenir monnaie courante dans un proche avenir car les terres disponibles sont à la baisse en même temps que la demande pour les ressources augmentent. Et quand on sait que le Sud disposent d'une abondance de terres que le Nord pourrait considérer comme étant à bon marché, les pays en voie de développement pourraient facilement se laisser tenter par des cessions rapides de terres et il en va également ainsi des ressources souterraines. Les ressources naturelles sont de plus en plus souvent au centre des intérêts et comme le souligne à propos Johny Rabenantoandro de QMM/RioTinto dans l'autre préface de ce numéro, il nous faut commencer par apprécier la richesse de la biodiversité et la sauvegarder pour l'avenir de nos enfants. Dès lors, on peut se poser des questions pertinentes sur la façon d'appréhender les changements sociaux, environnementaux et économiques, ou encore sur les moyens qu'ont les systèmes écologiques et sociaux d'encaisser les variations en matière de disponibilité et de demande de ressources sans qu'ils ne s'effondrent.

Nos questions sur l'avenir de Madagascar ne trouveront pas un terme ici, car nous avons la chance de vous présenter dans ce numéro des contributions qui abordent justement ces thèmes. Dans la nouvelle rubrique SPOTLIGHTS, Jeffrey Sayer (IUCN) nous éclaire sur des concepts qu'il connaît

bien et défend les mosaïques de paysages pour réconcilier la protection de la nature et le développement. Dans une autre contribution, William McConnell de la Michigan State University nous propose une revue de la modélisation de l'influence humaine. La modélisation est un sujet émergeant à Madagascar comme ailleurs et peut s'avérer être un outil utile pour mieux comprendre certains schémas d'occupation des terres comme dans les études portant sur les moyens de subsistance ou d'autres recherches sur des questions sociales. Une autre contribution est basée sur des enquêtes menées auprès des pêcheurs et riziculteurs des marais de l'Alaotra afin d'appréhender leurs conditions de vie et leurs besoins. Et nous nous posons tous les mêmes questions : comment concilier protection de la biodiversité et conditions de vie de l'humanité ? Comment protéger les espèces rares ou menacées et leurs écosystèmes sans compromettre les besoins vitaux des gens ? Pour répondre à ce genre de questions, il nous faut absolument étendre nos connaissances de base pour mieux comprendre les systèmes écologiques au sein desquels on retrouve la protection de la nature et le développement. Les auteurs de deux autres contributions portant sur les lémuriens et sur les oiseaux apportent leur pierre à cet édifice de connaissances.

En résumé, bien que ces périodes de changement et de bouleversement retournent des systèmes apparemment stables, il existe également l'espoir que la libération de l'énergie à laquelle nous assistons actuellement à Madagascar se soldera par une « boucle de Holling » avec de nouvelles occasions à saisir. Nous devrions profiter de cet élan pour libérer encore plus d'énergie et la concentrer dans la recherche pour que nous puissions étendre nos connaissances de base, mieux comprendre les connexions des systèmes et renforcer notre résilience pour nous adapter plus rapidement aux futurs changements. Car la seule certitude que nous ayons pour le futur de Madagascar est le changement.

Patrick O. Waeber, Rédacteur Fondateur
Lucienne Wilmé, Rédacteur en chef

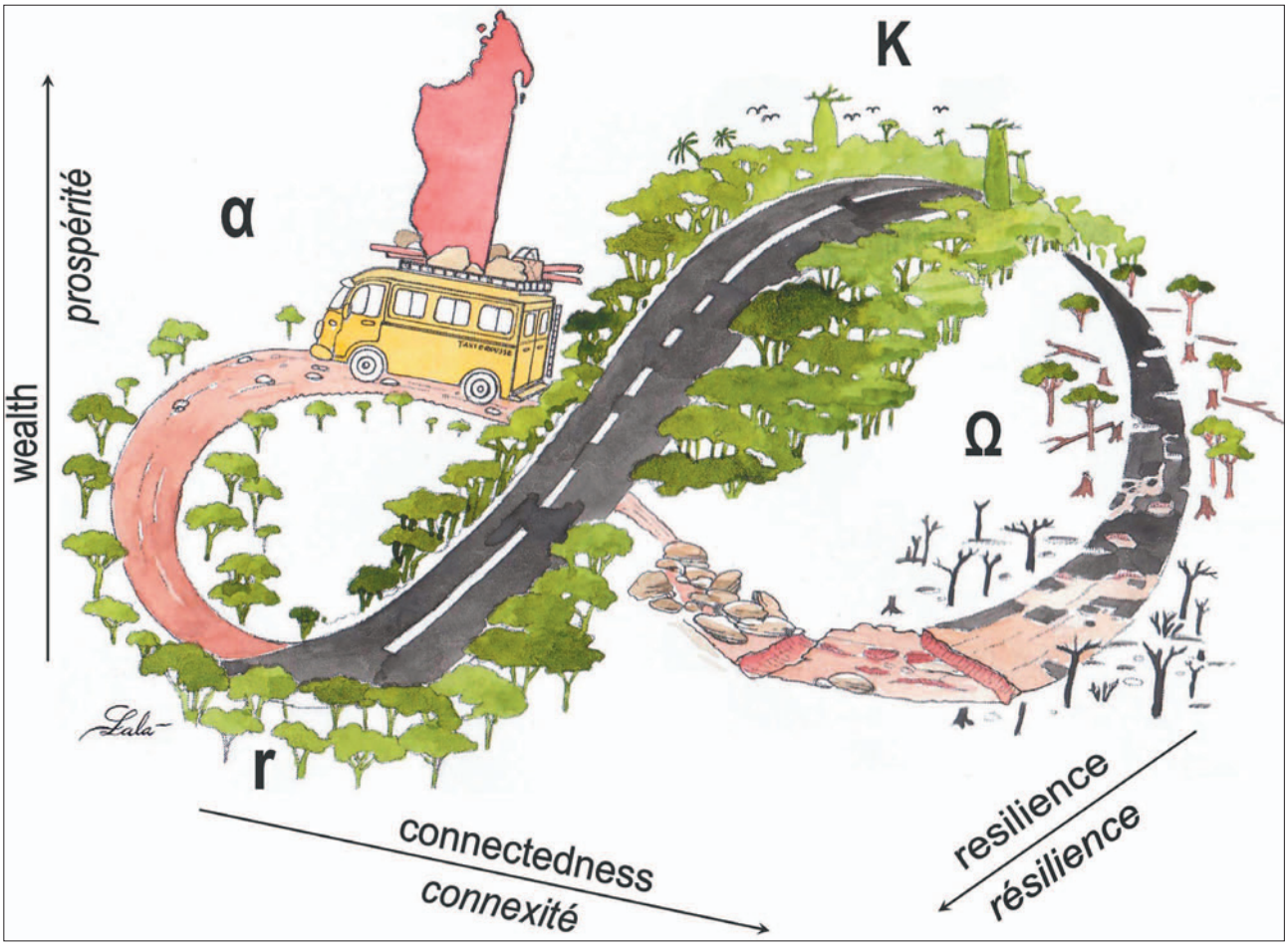

Figure adopted from Gunderson, L. H. and Holling, C. S. (Eds.) 2002. Panarchy: Understanding Transformations in Human and Natural Systems. Island Press, Washington, D. C.

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FOREWORD

Reflections on a changing Madagascar

When I was asked to write the foreword for this important journal I was honored. Honored and troubled. What could a conservation ecologist say about development that was particularly relevant at such a critical time in Madagascar's history? During such a distinct period of uncertainty and change, what reflection might I offer that would be helpful, hopeful, and reasonable? Over the weeks, I have witnessed the turmoil of a country searching for inner peace while dedicated individuals continue to work towards improving lives and safeguarding the future of this wonderfully unique island. And in struggling with what to say in the face of inevitable change, three concepts keep coming to mind. The first two concepts come from my ecology training; the last emerges from my experiences as a development professional. These concepts are neither new nor ground-breaking. They certainly won't solve all the challenges of Madagascar conservation and development today. Yet together, these three concepts may offer some orientation for continued integrated conservation and development work in a changing Madagascar.

The first concept is connectedness. Connections are the key to ecology. Species and ecological processes linked in one complex system. Natural elements connected to people and culture through a complex web of relationships, desires and values. At this critical juncture in Madagascar's history, it seems imperative to both understand and exploit these connections. Healthy people cannot exist in an unhealthy environment. Political decisions are intimately connected to the well-being of people and the survival of their natural resource base. As choices are made, it is imperative that decisions not be taken in short-term haste to meet the pressing needs of today at the expense of the longer term needs of both today and tomorrow. A thoughtful process that embraces the connectedness of all Malagasy people to each other and their natural world is a difficult one. But by keeping these connections intact, by ensuring that each part of the system is understood and valued, a more rewarding, equitable and sustainable future can be secured.

The second concept is resiliency. Resiliency relates to the ability to withstand and recover from shocks and perturbances while maintaining functionality and equilibrium. It is clear that Madagascar is experiencing shocks. More frequent and intense cyclones, changing climatic patterns, severe periods of drought and unprecedented pressure for natural resources tax the recovery abilities of humans and the natural world alike. Recent socio-political changes are undoubtedly testing the resiliency of Malagasy society. New pathways for development in Madagascar must offer resilient options for the Malagasy people. The sharing of development dividends amongst a larger number of citizens across Malagasy society will enhance the resiliency of Madagascar as a whole. Safeguarding natural assets, including soil, water, forests, fisheries and biological diversity, creates a social safety net that will allow Madagascar to cope in the short-term, and thrive in the long-term.

The last concept is reconciliation. Of all the concepts, this is probably the most difficult one. In the financial world, we reconcile our accounts. Inputs and outputs, income and expenses are scrutinized to ensure that the ledger adds up at the end of the day. But such reconciliation demands an honest and clear accounting system where incomes are transparent and real costs are understood. In Madagascar, this means making development decisions that incorporate the real costs of leaving marginalized and vulnerable members of society behind, real costs of irrevocable and detrimental changes to the functioning of natural systems, real costs of losing species, and the real cost of not being able to adapt and cope with climatic changes. It means internalizing and making rationale decisions about these costs now, so that Malagasy children will be able to ensure that the ledger adds up at the end of the century.

But there is another definition of reconciliation, the coming together of opposing parties to resolve conflict and find peace. Undoubtedly, this is the hardest part. It involves open and participatory dialogue that teases out seemingly intractable issues to find balanced solutions that everyone can live with. Reconciliation cannot be forced – people must want to engage, must be willing to expose truths and be open to exploring other perspectives. With a commitment to compromise and dignity, reconciliation brings healing and harmony.

It is incumbent upon us, the conservation and development community, to support the Malagasy people in efforts to come together and embrace the linkages between people and their natural world through a process of reconciliation and thoughtful weighing of trade-offs to ensure a resilient Madagascar. The lessons and articles we share through this journal offer important insights and lessons to move us in that direction.

Doreen Robinson

USAID Madagascar

The information and views presented in this article are solely those of the author and do not necessarily represent the views or the positions of the U.S. Agency for International Development or the U.S. Government

PRÉFACE

Réflexions sur Madagascar, pays en évolution

Je me suis sentie en même temps honorée et troublée quand ce grand journal m'a fait honneur en m'invitant à écrire une préface. Quel sujet pertinent sur le développement pourrait donc écrire une éco-conservationniste à un moment si critique de l'histoire de Madagascar ? Que pourrais-je proposer comme réflexion qui soit à la fois utile, empreinte d'espoir et raisonnable pendant cette période marquée par l'incertitude et le changement ?

Pendant des semaines, j'ai été le témoin de l'agitation d'un pays à la recherche de paix intérieure pendant que des gens dévoués poursuivaient leurs efforts afin d'améliorer les conditions de vie et préserver le futur de ce pays merveilleux et unique. Alors que ces pensées me taraudaient face à un

changement inévitable, trois concepts me sont venus à l'esprit. Les deux premiers me viennent directement de ma formation en écologie alors que le dernier a été façonné par mon expérience professionnelle acquise dans le développement. Ces concepts ne sont ni nouveaux ni révolutionnaires et ils ne vont vraisemblablement pas constituer la solution à tous les problèmes du développement et de la conservation de Madagascar actuels. Cependant, ils pourront conjointement tracer une voie dans la poursuite des travaux de conservation et de développement intégré pour ce pays en pleine évolution qu'est Madagascar.

Le premier concept porte sur la connexité. Les connexions sont les clefs de l'écologie avec les espèces et les processus écologiques qui sont liés dans un système complexe. Nous avons ici des éléments naturels reliés à des gens, à leur culture au sein d'un réseau complexe de rapports, de désirs et de valeurs. À ce moment délicat de l'histoire de Madagascar, ces connexions doivent être à la fois comprises et exploitées. Des gens sains ne peuvent vivre dans un environnement malsain. Les décisions politiques sont intimement liées au bien-être des gens et à la survie de leurs ressources naturelles de base. Lorsque des choix sont faits, il est impératif que les décisions ne soient pas prises dans la hâte du cours terme pour satisfaire des besoins immédiats au détriment des besoins à plus long terme actuels et futurs. Un processus réfléchi qui englobe l'ensemble des rapports connexes régissant tous les habitants de Madagascar entre eux mais aussi avec leur patrimoine naturel n'est pas aisé. Cependant c'est en maintenant ces liens, en assurant que chaque élément du système est compris et mis en valeur, qu'un avenir plus prometteur, plus équitable et plus durable peut être assuré.

Le deuxième concept porte sur la résilience. La résilience se réfère à la capacité de résister et de se ressaisir des chocs et perturbations tout en maintenant fonctionnalité et équilibre. Il est clair que Madagascar est en train de subir des chocs. Des cyclones plus fréquents et plus intenses, des changements climatiques, de graves épisodes de sécheresse et une pression sans précédent sur les ressources naturelles mettent en péril les capacités de se recomposer, qu'il s'agisse des gens ou de la nature. Les changements socio-politiques récents mettent assurément à l'épreuve la résilience de la société malgache. Les nouvelles voies pour le développement de Madagascar doivent fournir des options résilientes pour les gens de Madagascar. Le partage des acquis du développement entre un plus grand nombre de citoyens de la société malgache améliorera la résilience de Madagascar dans l'ensemble. Sauvegarder le patrimoine naturel, y compris la terre, l'eau, les forêts, la pêche et la diversité biologique crée un filet de sécurité social qui permettra à Madagascar de composer à court terme et de prospérer à long terme.

Le dernier concept, qui est sans doute le plus ardu des trois, est le rapprochement. Dans le monde financier, nous procédons à des états de rapprochement de nos comptes. Des entrées et des sorties, des revenus et des dépenses qui sont contrôlés pour s'assurer que les soldes dans les livres s'équilibrent en fin de journée. Mais un tel rapprochement requiert un livre comptable honnête et clair dans lequel les revenus sont transparents et les charges réelles sont comprises. À Madagascar, cela signifie de prendre des décisions en matière de développement en incorporant les coûts réels liés au fait que certaines personnes marginalisées ou vulnérables de la société soient écartées du processus, les coûts réels des changements irrévocables et préjudiciables apportés au fonctionnement des systèmes naturels, les coûts réels de la perte d'espèces naturelles et les coûts réels liés au fait de ne pas être capable de s'adapter et de faire face aux changements climatiques. Il s'agit d'absorber ces coûts et de prendre dès à présent des décisions raisonnables à leur propos de sorte que les enfants de Madagascar seront capables d'assurer que les soldes dans les livres s'équilibrent à la fin du siècle.

Il existe aussi une autre définition du rapprochement, celle de la rencontre de parties en opposition pour résoudre un conflit et trouver la paix. Il s'agit sans nul doute de l'acte le plus difficile à jouer car il repose sur un dialogue ouvert et participatif jusqu'à la limite des situations inextricables afin d'aboutir à des consensus équilibrés où chacun peut se retrouver. Le rapprochement ne peut être forcé – les gens doivent vouloir s'engager, doivent être disposés à exposer des vérités et s'ouvrir pour rechercher des alternatives. Avec la dignité et la volonté réelle de dialoguer, le rapprochement peut panser les plaies et apporter l'harmonie.

Il nous incombe, à nous membres de la communauté de la conservation et du développement, de soutenir les Malgaches dans leurs efforts pour se rassembler et renforcer les liens entre les gens et la nature dans un processus de rapprochement avec des compromis soigneusement réfléchis pour assurer la résilience de Madagascar. Les leçons et les articles que nous partageons dans ce journal constituent ainsi des aperçus importants pour nous mener sur cette voie.

Doreen Robinson

USAID Madagascar

Les informations et points de vue contenus dans ce message expriment la pensée personnelle de l'auteur et ne représentent pas forcément la position de U.S. Agency for International Development ou du Gouvernement des États-Unis.

PRÉFACE

La Biodiversité, garant de notre bonheur

Dans un monde où les seuls choix, imposés par une soif d'idéal artificiel et rationnel, sont de se développer ou de mourir, Madagascar doit impérativement prendre suffisamment de recul pour mieux sauter vers l'avenir. Un recul peut-être perçu comme un geste de retrait, de lâcheté mais pourrait aussi être un élan de sagesse qui exprimerait une réflexion et la lecture d'un parcours destiné à préparer les stratégies de mise en œuvre, d'identification et de gradation des objectifs contribuant au vrai développement du pays.

Malheureusement, notre siècle ne fait pas exception aux autres en contribuant à la tendance vers la rareté des ressources naturelles. Cette tendance se manifeste par une compétition de plus en plus directe entre les ressources naturelles renouvelables et celles qui ne le sont pas. Des choix sont à faire entre la sauvegarde des espèces et l'exploitation des richesses du sous-sol comme c'est le cas pour les sources d'énergie. Mais la question qui se pose est de savoir si nous avons vraiment le choix ; c'est une question à laquelle il est très difficile de répondre. Conformément à la définition du développement durable donnée par le premier ministre norvégien il y a plus de vingt ans, peut-on considérer que la valeur des ressources exploitées prenne en compte l'amortissement destiné aux investissements nécessaires aux générations futures ? Dans ce combat entre la protection des espèces et l'exploitation des ressources, qui sera le premier à mettre la biodiversité au tapis ? Le développement ou la pauvreté ?

Pour Madagascar, l'enjeu est assez délicat car désormais chacun est invité à réfléchir de façon active sur la meilleure façon de préparer l'avenir. Dans ce contexte, la participation par les publications peut être légitimement considérée comme un investissement pour le futur développement de Madagascar. Mais quel développement ? C'est justement ce qu'il faut identifier et définir avec une grande prudence et avec fermeté. Car il nous faut des références et des traces pour constituer une ligne de tendance franche à adopter, accepter et transmettre de génération en génération. La publication des résultats de recherche dans tous les domaines peut être considérée comme la pierre d'achoppement de l'échafaudage d'une telle armature.

Par ignorance ou en connaissance de cause, on nous dit à nous Malagasy, que nous sommes riches mais aussi très pauvres. Face à un tel paradoxe, la fierté devra se placer par rapport à une certaine valeur de référence. Mais à part la valeur économique, quel autre type de valeur peut-on considérer ? Il est donc important de se rappeler que par la rédaction de nos travaux dans une publication de référence, nous nous engageons à contribuer à définir les diverses valeurs des ressources que nous léguons à l'humanité. Nous assistons déjà à la croissance continue des valeurs des diversités moléculaires, génétiques et morphologiques, et actuellement, ceux qui sont conscients des risques inhérents au changement climatique commencent aussi à accorder une importance 'économique' aux services d'intérêt général offerts par les écosystèmes.

Jusqu'ici, on peut dire que la nature a pris soin des Malagasy. Il est temps de renverser la tendance et dire que le temps est venu pour les Malagasy de prendre soin de la nature. À l'image d'un enfant, devenant adulte, qui va témoigner sa reconnaissance à ses parents. Les visiteurs passant à Madagascar sont souvent étonnés de la résignation de la population par rapport à la pauvreté. On dit souvent que les Malagasy sont pauvres mais heureux. Est-ce que c'est possible ? La réponse peut-être oui dans le sens ou malgré la pauvreté économique du pays sa richesse biologique arrive encore à rendre les gens heureux pour vivre au jour le jour. En coupant un arbre, en pêchant, en vendant les orchidées sauvages, et la liste est longue, les Malagasy arrivent encore à afficher un sourire. En suivant la tendance, il se peut alors que le bonheur des Malagasy se dégrade de jour en jour avec la détérioration de son patrimoine naturel.

Pour terminer, après une quinzaine d'année de travaux de recherches sur le terrain dans différentes régions de Madagascar, il n'est peut être pas si prétentieux d'affirmer que l'identité du pays est étroitement lié à sa biodiversité. Que ce soit dans la vie ou dans la mort, dans la joie ou dans le malheur, en ville ou en brousse la plupart des Malagasy retournent toujours vers la nature pour se réfugier. Le vrai développement du pays dépendra en grande partie de la prise de responsabilité conjointe vis-à-vis du respect de l'environnement. Si l'écosystème reste encore la plus grande entreprise qui fait vivre la majorité des Malagasy, il nous appartient de faire en sorte que cette entreprise qui porte notre futur ne connaisse pas la faillite.

C'est avec une grande humilité que j'ai essayé d'écrire cette préface en espérant que je peux stimuler des inspirations en faveur de notre entreprise du futur qu'est « La Biodiversité ».

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FOREWORD

Biodiversity, guarantor of our happiness

In a world where the only choices, imposed by a thirst for an artificial and rational ideal, are to develop or to die, Madagascar must step back sufficiently in order to prepare for the future. Although stepping back may be perceived as a gesture of retreat or cowardice, it may also be considered a strategy which expresses the reflection of a path destined to prepare for the identification and implementation of strategies contributing to the country's true development.

Unfortunately, our century is no exception when it comes to the decline of natural resources. This trend manifests itself through increasing direct competition between renewable and non-renewable natural resources. Choices must be made between safeguarding species and the exploitation of the Earth's

wealth below its surface, as is the case for the majority of energy sources. However the question is whether we are entitled to the choice, a difficult question to answer indeed. In accordance with the definition of sustainable development offered by the Norwegian Prime Minister more than 20 years ago, can we consider that the value of exploited resources takes into account the amortization destined for the investments necessary for future generations? In this battle between the protection of species and the exploitation of resources, which will be the first to knock-out biodiversity? Development or poverty?

For Madagascar, the stakes are delicate because henceforth everyone is invited to contemplate the best way to prepare for the future. In this context, participation from publications may be legitimately considered as an investment for the prospective development of Madagascar. And which development? This is precisely what requires identification and definition with great caution and resolve. This is because we need guidelines to form a line of approach which can be adopted and delivered from generation to generation. The publication of research results in all fields may be considered as the basis for such a construct.

Through ignorance or shrewdness, we Malagasy are told that we are rich and yet also very poor. In the face of this paradox, pride will have to be placed in relation to a certain value of reference. Apart from economic value, what other value might we consider? It is thus important to remind oneself that through writing our work in a reference publication, we engage ourselves in the contribution of defining the diverse values of resources that we leave behind for humanity. We are already witnessing the increasing value of molecular, genetic and morphologic diversity. Now those who are conscious of the inherent risks of climate change are also beginning to assign 'economic' importance to the services offered by ecosystems.

We can say that until now, nature has cared for the Malagasy. It is time to reverse this trend and say that the time has come for the Malagasy to take care of nature – like an image of a child growing into adulthood, expressing gratitude towards his or her parents. Visitors to Madagascar are often surprised by the population's resignation towards poverty. We often say that the Malagasy are poor yet happy. Is this possible? The answer could well be yes in the sense that although the country may be financially poor, the biological richness affords enough happiness live from day to day. Through the cutting of a tree, fishing, selling wild orchids, and the list is long, the Malagasy are still able to smile. Consistent with this trend, the Malagasy's happiness could decrease day by day with the deterioration of his or her natural heritage.

In conclusion, after some 15 years of field research in different regions of Madagascar, it may not be so pretentious to state that the country's identity is closely knit to its biodiversity. Whether in life or in death, in happiness or in sadness, in the city or in the bush, most Malagasy always return to nature for refuge. The country's true development will depend on a partnered responsibility to respect the environment. If the ecosystem still remains the largest enterprise which allows the majority of the Malagasy to make a living, it belongs to us to make sure that this enterprise, which carries our future, does not fail commercially.

It is with great humbleness that I attempted to write this preface in the hope that I can stimulate inspiration in favor of our future enterprise, 'Biodiversity'.

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SPOTLIGHTS

Can conservation and development really be integrated?

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ABSTRACT

Most biodiversity conservation projects in poor tropical countries also aspire to alleviate the poverty of local people. The results of these integrated conservation and development projects have often been disappointing. This paper argues that it would be impossible for both practical and ethical reasons for conservation programmes to ignore the needs of poor people who live in and around the natural areas that we seek to conserve. The problem is not whether we should attempt to integrate conservation and development but rather how we should attempt to do so. Recommendations are made for a number of principles that should underlie such programmes. It is argued that they should operate at the scale of landscape mosaics, they should be firmly rooted in local social processes and they should make the trade-offs between conservation and development explicit. Less effort should go into planning them and more into working with local stakeholders to explore options and find solutions that meet both local livelihood needs and global conservation goals.

RÉSUMÉ

La plupart des projets qui portent sur la conservation de la biodiversité dans les pays pauvres distribués sous les tropiques tentent également d'améliorer la qualité de vie des populations riveraines. Les résultats de ces projets «intégrés» ont cependant souvent été décevants. Dans cet article je prends position pour défendre que pour des raisons à la fois pratiques et éthiques il serait insensé de ne pas prendre en compte les intérêts des populations directement impliquées dans ces programmes intégrés de protection de la biodiversité. La question n'est pas simplement de les impliquer ou ne pas les impliquer mais il s'agit davantage d'identifier de nouveaux modèles pour que leur implication devienne réalité. La conservation et le développement sont inéluctablement liés et ne peuvent pas être considérés comme deux entités distinctes. Je propose ainsi quelques principes de bases à respecter dans ces programmes intégrés afin d'assurer les meilleurs chances de réussite. Ces programmes devraient intervenir à l'échelle des territoires qui abritent les biotopes des espèces à protéger ainsi que les zones occupées ou exploitées par les populations locales. Ils devraient trouver leurs racines au plus profond de la dynamique des sociétés concernées et être en mesure de montrer clairement les impacts des actions de conservation sur les moyens d'existence des peuples. Il s'agirait ainsi de réduire les interventions d'experts extérieurs dans la planification pour favoriser et encourager la recherche d'alternatives et de solutions concertées avec les acteurs locaux pour réussir aussi bien à protéger la nature qu'à améliorer les conditions de vie des populations humaines.

KEYWORDS: Conservation, development, landscape, livelihoods, biodiversity.
MOTS CLEF : conservation, développement, paysage, subsistance, biodiversité.

INTEGRATING CONSERVATION AND DEVELOPMENT

Madagascar is a country with high levels of poverty – at least as defined by development assistance agencies. It is also home to biodiversity that is valued as a global resource. As a result a lot of the conservation initiatives in the country are invested in attempts to simultaneously address the two distinct problems of alleviating poverty and conserving biodiversity. There is now a growing skepticism as to whether these integrated approaches really work. This paper argues that integrating conservation and development is more important than ever. The lack of success in the past stemmed from the attempts to achieve the integration through externally imposed projects constrained by the procedures of the external actors who funded them. Although most conservation and development agencies espouse the virtues of locally driven processes few of them actually practice what they preach.

Throughout the world the integration of conservation and development has been the mantra of conservation organizations for more than four decades. Integrated approaches were first motivated by the belief that traditional agricultural practices and poaching were the overriding threat to the preservation of tropical nature. Modernizing peasant agriculture, linking the poor to the market economy, giving them land rights and introducing new agricultural technologies were all seen as key to improving their livelihoods whilst at the same time reducing their demands for new land. Up until the late 1980s and early 1990s the conventional conservation wisdom was that the major threat to tropical forests came from shifting agriculture.

More recent studies have shown that it was wrong to blame all the problems on shifting agriculture (Geist and Lambin 2002). There were places like eastern Madagascar, where *tavy* was, and remains, a real problem for the maintenance of natural forests,

but in many parts of the world long-cycle shifting agriculture was nowhere near as damaging to nature as was often claimed. Amongst some environmental groups logging was also portrayed as a major threat but there is little evidence that logging alone has ever done much permanent harm to tropical forests (Pearce et al. 2003). Logging has been a problem when associated with demand for agricultural land and more significantly as a driver of corruption and bad governance but logging alone did not destroy forests. Recent studies by FAO and others confirm that most tropical deforestation is planned conversion to things like soybeans in the Matto Grosso, oil palm in southeast Asia or tree crops in West Africa. Most scenarios for the tropics see large-scale development of agro-industries to feed the world's projected population of 9 billion meat eating, car driving, middle class citizens as the main future threat to nature.

One can debate whether the demand for tropical products by the rich world is a threat or an opportunity for tropical biodiversity and the livelihoods of rural people. Expanding demand for food and biofuels certainly increases pressure for land conversion but it also creates jobs and increases incomes so that rural people can invest in more efficient and intensive agriculture. Increased external demand in a context of good local governance is probably positive but when there are governance failures and corruption is rife then market pressures can be very damaging.

In the days when we thought that people destroyed nature to meet their subsistence needs it made a lot of sense to work with populations around critical natural areas to improve the productivity of their farming. Bee keeping, agro-forestry, non-timber forest products all offered plausible ways of sustaining livelihoods without destroying more forests (Roe and Elliott 2008). The problem was that the rural poor were not satisfied with simply sustaining their existing livelihoods; they wanted to escape from their subsistence ways of life. They wanted better education for their children; better health care; and jobs and income so that they could enjoy some of the benefits that they observed in the rich world. Continuing to subsist but in a slightly more environmentally friendly way, the eco-development paradigm, did not meet their expectations. If they were aware of a new technology that showed promise of being profitable then their zeal for clearing forest was intensified. When people discovered booming markets for the cinnamon produced in Sumatra they redoubled their efforts to clear forest in Kerinci National Park. When raising cattle was profitable in the Amazon then landless people invaded the forest and established ranches (Kaimowitz et al. 2005). Their investment costs were low and securing de facto title to the land was an important motivating factor.

Most rigorous studies of attempts to address conservation problems through local eco-development interventions, for instance in buffer zones around critical areas, have concluded that there was little evidence that they did much either for local livelihoods or for conservation (McShane and Wells 2004). There is circumstantial evidence that in many cases these projects may even have created local poles of development activity that increased the pressure on natural areas. In many parts of the tropics the pressure has only been taken off forests when people have found it more attractive to move to the cities to work in services or factories. The manufacturing boom of the 1980s and 1990s in southeast Asia did more to eliminate shifting agriculture than any attempt at integrating conservation and development. However the basic problem remains that people will always clear forest when it is profitable to do so. Profitability is determined by the likelihood of making money versus the likelihood of being punished for illegal land clearing.

In 2008-9 the world entered a food crisis. Prices of commodity crops rose dramatically and once again there were predictions of famine on a grand scale. The yield gains obtained by the 'green revolution' are not being maintained and many see the solution to the world's food problems as lying in massive expansion of agriculture into forest lands, especially in Africa. Most of this expansion will have to be into areas previously considered marginal for conventional agriculture but where improved crop varieties and modern farming technologies, fertilizers and pesticides now make agriculture possible. This pressure for more land will come at a time when huge investments are planned to put infrastructure into the remotest corners of the tropical world. New roads and railways are being built to give access to minerals, timber and hydroelectric schemes or simply to facilitate the rule of law in remote areas. This burgeoning infrastructure will greatly increase the profitability of agriculture in hitherto inaccessible areas and a vicious circle of forest destruction is likely to follow. In the face of these challenges our traditional approaches to integrating conservation and development will be totally inadequate.

There is a strong body of opinion that in the face of such growing threats and in recognition of the poor performance of ICDPs (Integrated Conservation and Development Projects) we must fall back on fortress conservation or 'fences and fines'. It is argued that conservation money should be invested in strictly protected areas and law enforcement. However, I would like to align myself with many others who argue that this would be a mistake (for example Wilshusen et al. 2002). The challenges we are facing require more than ever that conservation and development be integrated (Wells et al. 2004). But this integration must be in new ways and at different scales (Sayer et al. 2008).

PRINCIPLES FOR NEW APPROACHES TO INTEGRATING CONSERVATION AND DEVELOPMENT

I would offer the following principles for future endeavors:

WORK AT LARGE SPATIAL SCALES – OPERATIONALISE THE LANDSCAPE CONCEPT Attempting to alleviate poverty by working at a very local scale with the small numbers of people who live in and around features of conservation concern is unlikely to be effective. Such interventions may be useful in building social capital and defusing tensions and even in learning about the area by tuning in to local knowledge. But significant improvements in livelihoods rarely come from marginal improvements to existing livelihood practices; they almost always come from the new opportunities presented by external investment, new infrastructure and access to markets. To improve livelihoods one should not focus on what the poor are doing now but on what they might do in the future in growing economies. Macro-level changes in investment and infrastructure drive development not incremental changes in subsistence livelihood practices. Sacrificing some natural habitat for an agro-industrial plantation will do far more to alleviate poverty than marginal improvements in agro-forestry or non-timber forest product systems (see for instance Sandker et al. 2007). Understanding

the underlying drivers of change and the potential routes out of poverty is essential and this is best achieved at a landscape scale – that is to say a scale that includes a diversity of landscape elements and includes natural habitats, agricultural and industrial areas. Conservation programmes must be set in the context of the most probable changes in the social-ecological system and not based upon an idealized plan that does not recognize the real aspirations of people.

LANDSCAPES AND CATCHMENTS ARE OFTEN APPROPRIATE SCALES Working at these larger scales forces one to cut across sectoral boundaries and to engage with a broader diversity of stakeholders. It also helps to understand broader developmental trajectories and to focus on the big issues and not the local and marginal. Landscapes are the right scales at which to engage with civil society and to develop the social movements that can underpin efforts to achieve sustainability. Landscapes encompass all of the elements that contribute to people's livelihoods – both from their farms and from surrounding forests. People are often making extensive use of lands that are the habitats of the species of conservation concern. New decentralized natural resource management arrangements often fit in nicely with the landscape scale. Lastly, within a landscape there is room to manœuvre – losses in one part of a landscape may be offset against gains elsewhere. The Adapting Mosaic scenario developed under the Millennium Ecosystem Assessment provides a good conceptual framework for landscape scale interventions (Millennium Ecosystem Assessment 2005).

LISTEN, LEARN AND ENGAGE WITH STAKEHOLDERS Expert missions that parachute in, conduct diagnostic studies and prescribe solutions are a sure recipe for failure. It takes time and patience to become attuned to the real issues in a complex conservation landscape. The principles of 'appreciative enquiry' provide useful guidance on how to engage with local populations (Cooperrider et al. 1995). Stakeholder meetings are needed and consensus must be built but it is risky to jump too quickly into setting up formal stakeholder platforms. Dealing with the conflicting interests of diverse groups can be difficult. It is better to start with a smaller number of sympathetic local stakeholders and gradually expand the network as opportunity and needs arise. There is a common myth that simply convening a large group of people with conflicting interests will lead rapidly to consensus on win-win outcomes. Win-wins are rare and one is usually seeking simply to win a little more and lose a little less. Stakeholder platforms are important but outsiders have to invest a lot of time in really understanding the dynamics of local interactions and how local behaviors might be changed.

EXPLORE SCENARIOS An excellent way of engaging with stakeholders and sharing understanding of potential change is to explore those scenarios for the future that would meet their developmental needs whilst also achieving conservation. Using simple drawing exercises where different stakeholders draw their best and worst case future scenarios provide a very good entry point for discussions. If skilled facilitation is available then building simple simulation models to explore scenarios in a more quantitative and rigorous way can be valuable. Both visualization techniques and modeling often produce counter-intuitive results (van den Belt 2004).

IDENTIFY INDICATORS Working with local stakeholders to identify simple indicators of progress towards the preferred scenario is very effective in focusing debate and providing feedback for adaptive management (Bell and Morse 1999). Indicators should sit in a framework that covers both environment and development. The capital assets framework has been used with success at a landscape scale. It allows trade-offs between losses of natural capital and gains in human, social and built capital to be assessed and negotiated (Sayer et al. 2006). Reed et al. (2008) provide a compelling rational for working through local people to derive indicators.

DO NOT PLACE TOO MUCH EMPHASIS ON FORMAL PLANNING Having clarity on the overall goal of an intervention is essential (Lee 1993). But it is a mistake to lock-in too early to a specific pathway to that goal. Maps and plans prepared by experts can look very convincing but they can also mask numerous assumptions and can exclude important realities of local people. Seeking solutions rather than developing blue-prints provides a better route forward in any development activity (Easterly 2008). Muddling through provides a better conceptual basis for engagement than detailed design (Sayer et al. 2008).

BASE CONSERVATION PLANS ON DESIRED OUTCOMES NOT PERCEIVED THREATS Conservation often focuses on protecting pristine nature against external threats. Threat-based conservation places conservationists in a permanently defensive mode of operation and is difficult to reconcile with the pursuit of a development agenda. It is better to take an outcome-based approach and work towards sets of outcomes that will provide an optimal balance between conservation and development benefits. Negotiated agreement on desired scenarios provide the best basis for moving forward but one has to recognize that these are complex systems and constant adaptation and course adjustment will be needed (Sayer and Campbell 2004, Sayer and Maginnis 2005).

SET REALISTIC GOALS FOR BIODIVERSITY Seeking to conserve all biodiversity is often not a realistic objective. In most landscape mosaics inhabited by poor people development will inevitably cause some losses of biodiversity. Not all biodiversity has equal value and not all can be maintained. Setting realistic, measurable and locally relevant biodiversity objectives will provide a sound basis for the negotiation of trade-offs. Even the Convention on Biodiversity in its Ecosystem Principles recognizes that biodiversity conservation must be a question of societal choice – with local societies having an important influence on the decisions. It is important to recognize that local people may have their own priorities for biodiversity that differ from those of outside conservation groups. Building on these may provide a sound basis for securing local buy-in (Sheil et al. 2006). It is also important to recognize that sustainable use of biodiversity may be a more attractive option for local people than total protection. If people can benefit from using a species they are more likely to conserve it .

CHOOSE LEADERS OF INTEGRATED CONSERVATION AND DEVELOPMENT PROGRAMMES WITH THE RIGHT QUALITIES Perhaps my overarching set of suggestions concerns the attitude and competencies of the leaders of conservation programmes. There is a tendency for programme leaders to be selected on the basis of their ability to deal with donor requirements. Someone who is good at log-frames and spread sheets will be preferred to someone who is happy to live in the local community and learn the local language. The success or failure of projects depends very heavily on the competence, sensitivity and adaptability of the programme leader. Table 1 contrasts the qualities that have

TABLE 1. The qualities needed to lead conservation and development initiatives

Old paradigm	New paradigm
Analysis and Diagnosis of the situation	Listening and learning
Planning	Seeking
Spatial plans and maps	Scenarios
Teaching and persuading	Sharing experiences and learning together
Setting goals and targets	Exploring options
Managing and controlling	Creating space for others and facilitating
Monitoring and evaluations	Seeking feedback
Fixed end point	Adapting mosaic
Sustainability	Resilience
Hiding mistakes	Learning from mistakes

traditionally been sought in programme leaders under a conventional development paradigm and suggests an alternative profile for a new paradigm.

CONCLUSIONS

For both practical and ethical reasons conservation practitioners must continue to engage with local stakeholders and they must learn to see conservation situations through the eyes of the people most directly impacted by their actions. Although many projects that sought to reconcile conservation and development have yielded disappointing results there are also many examples where committed individuals have achieved success. They have usually been people who have made a long-term commitment to seeking conservation and development outcomes for a critical area or species. These people have worked pragmatically with local communities because that was where they found problems and opportunities. They have muddled through, often liberated by the absence of the constraints imposed by the rigid frameworks of development-assistance donors. These champions of conservation and development have often found common ground with local stakeholders and have been able to bring about a convergence of interests. I started this essay with the rhetorical question of whether it is time to give up on attempting the integration of conservation and development. My answer is an emphatic no. We must continue to seek to integrate conservation and development. But not in the form of pre-planned, time bound projects but rather through long-term engagement with the people whose livelihoods are intimately connected to the natural resources being conserved.

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Modeling human agency in land change in Madagascar: A review and prospectus

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ABSTRACT

Preserving Earth's biodiversity is one of the central challenges to global sustainability, and the task is complicated in developing countries by the need to avoid further compromising the ability of resource-dependent people to secure their livelihoods. The challenge is all the more daunting given the scarcity of resources available to the effort, necessitating reliable analyses of the role of human agency and the effects of various policy prescriptions. New sources of data and computational tools available to researchers over the past two decades have enabled the development of quantitative models of human agency in land change, including a special class known as spatially explicit models. This article explores advances in understanding human agency in land change in Madagascar in order to synthesize lessons learned and identify remaining challenges. It concentrates on the findings of a number of recent spatially explicit modeling efforts, identifying progress in accounting for human presence in the landscape. Other quantitative and qualitative studies point to the importance of a broad array of additional factors, particularly those reflecting interactions among agents. Bringing together the various perspectives on human agency in land change in Madagascar should enable them to better contribute to the formulation of policy that can balance protection of the island's biodiversity with securing the livelihoods of the Malagasy people.

RÉSUMÉ

La conservation de la biodiversité est l'une des pièces maîtresses de l'utilisation pérenne des ressources de la planète et la tâche est d'autant plus complexe dans les pays en voie de développement dans lesquels les moyens de subsistance des populations rurales sont étroitement liés à leur capacité d'accéder aux ressources naturelles. La tâche est aussi ardue que les ressources financières disponibles sont limitées, de sorte qu'il est important de bien comprendre comment s'articule l'organisation humaine autour des politiques et programmes de conservation mis en œuvre (l'expression 'organisation humaine' qui traduit '*human agency*' est employée ici pour désigner les activités physiques des hommes – comme les défrichements pour cultiver le riz – mais englobe aussi des dimensions éthiques, culturelles et légales qui pourraient être à l'origine de l'absence d'action – comme la menace de répressions du défrichement pour la culture du riz–étant entendu que l'organisation s'entend au niveau individuel mais aussi collectif en pouvant résulter d'une action ayant un impact réel sur le paysage ou de l'absence d'une telle action.) Grâce à de nouvelles sources d'informations mais aussi de nouveaux outils et procédés informatiques développés au cours des vingt dernières années, il a été possible d'élaborer des modèles quantitatifs portant sur l'organisation humaine dans les dynamiques des paysages en incluant une catégorie particulière dénommée '*spatially explicit*', à savoir un modèle explicitement spatial. Cet article aborde les progrès réalisés pour mieux appréhender l'organisation humaine dans la dynamique des paysages à Madagascar, récapitule l'apprentissage en la matière et formule les nouveaux défis à relever dans ce domaine.

Il apparaît clairement que pour comprendre le rôle de l'organisation humaine dans la dynamique des paysages, il faut commencer par aborder la présence et la distribution des gens dans l'espace. Les modèles existants ont nettement mis en relation la 'pression démographique' et la déforestation anthropique et cela depuis les travaux de Green et Sussman publiés en 1990. Cependant, les conclusions tranchées de l'époque ne sont pas aussi fiables qu'elles prétendaient l'être et plus particulièrement en ce qui concerne la relation de cause à effet entre la croissance démographique et les défrichements, de sorte que nous présentons quelques recommandations méthodologiques inspirées d'autres approches analytiques.

Les modèles existants ont confirmé les observations de Green et Sussman (1990) montrant un taux de défrichement réduit dans les régions à topographie accidentée mais ont aussi dévoilé l'importance d'un certain nombre d'autres facteurs tels que les infrastructures de transport, les différences d'accès des communautés rurales aux moyens de production, la sécurisation foncière et d'autres actions du gouvernement ou d'organisations non gouvernementales.

Au fur et à mesure que les modélisations rendent mieux compte du rôle de tels facteurs, elles devraient alors permettre d'évaluer plus précisément la pertinence des efforts déployés pour protéger la biodiversité. Cet aspect peut être envisagé avec un certain espoir bien que de manière préliminaire ; la conversion des forêts à des usages agricoles dans les aires protégées semble être réduite par rapport à cette même dynamique

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observée dans des aires comparables mais non protégées. Ces conclusions devraient être étayées au fur et à mesure que les modélisations seront en mesure d'intégrer d'autres facteurs dont l'importance sera révélée par diverses études scientifiques et qui portent aussi bien sur les contextes environnementaux que sur les interactions au sein des communautés humaines. L'intégration de ces diverses perspectives analytiques devraient permettre aux modélisations de contribuer à élaborer une politique pertinente pour protéger au mieux la précieuse biodiversité de l'île tout en assurant les moyens de subsistance des populations rurales de Madagascar.

KEYWORDS: Madagascar, conservation, land-use, spatially explicit model, human agency.
MOTS CLEF : Madagascar, protection de la nature, utilisation des terres, modèle explicitement spatial, organisation humaine.

INTRODUCTION

In 2003, the biodiversity conservation community was pleased to hear Madagascar's President, Marc Ravalomanana, outline a bold, new initiative to increase protection of the island's imperiled biodiversity. In what became known as the 'Durban Vision,' he pledged before the World Parks Congress that his government would triple the size of the country's network of protected areas by 2008 (Norris 2006). As this deadline approached, the government also began negotiating a 99-year lease with Daewoo Logistics for production of maize and oil palm destined for South Korea (Walt 2008). Together, these two policies directly concern about 10 % of the island's land area, and more than half of its arable land, making it more important than ever to accurately understand threats to biodiversity and the consequences of protection efforts.

The stakes in this endeavor are high: Much of the flora and fauna being targeted for protection are found nowhere else on Earth, but the financial resources available for conservation are quite scarce, and their efficacious use requires the application of state-of-the-art scientific methods (Ferraro and Pattanayak 2006). On the other hand, the act of protecting biodiversity requires a major shift of land-use rights away from some of the world's poorest farmers.

In response to the need to understand land-use dynamics in Madagascar, a number of models have recently been developed that aim to quantify the role of human agency in altering the island's landscapes (Table 1). These quantitative models form a new branch of a literature whose roots can be traced as far back as the work of Etienne de Flacourt in the middle of the 17 th century. This literature blossomed in the early 20 th century with the study of the island's natural history (a review can be found in Andriamialisoa and Langrand 2003). Scholarship on the human imprint on the island flourished in rich geographical and anthropological case studies of land-use in many parts of the island in the latter half of the century by, for example, Blanc-Pamard and Cambrézy (1995), Coulaud (1973), Kottak (1980), Kull (1998), Le Bourdiec (1974), Raison (1970), and Rakoto Ramiarantsoa (1995).

While those studies did involve the collection and analysis of quantitative information, several studies in the past decade have taken the additional step of developing quantitative models that specify mathematical relationships between land-use (the manifestation of human agency on the land) and a range of social and biophysical factors, using means such as regression analysis. The advantages of quantifying these relationships include the possibility of parsing the relative contributions of causal and contextual factors and the estimation of a degree of confidence in the assessment of those relationships. Thus, in principle, the recently developed quantitative models are more useful than earlier studies for the design and evaluation of policies and programs concerning land-use. Whether this is true is a central question of this review. One approach – spatially explicit modeling – has gained wide currency across disciplines, particularly within the integrative field of land-change science (Gutman et al. 2004, Turner II et al. 2007). The term refers to a class of models in which explaining the behavior of the system in question depends on consideration of the spatial relationships among variables (Kaimowitz and Angelsen 1998, Mladenoff and Baker 1999, Skole and Cochrane 2004, Walker and Solecki 2004). In the case of spatially explicit regression, the algorithms applied are no different from those applied elsewhere, rather it is the explicitly spatial nature of the input variables, and sometimes the spatial interpretation of the results, that distinguishes this approach.

The approach enables the consideration of landscape variables, such as land cover and its underlying topography, which can often be made available at relatively high spatial resolution. As a result, large numbers of observations can be used in 'natural experiments' that isolate the effect of certain variables of interest, particularly those resulting from government policies and programs, on an outcome, like deforestation. In effect, locations subjected to a localized treatment – such as the construction of a road, or land-use restrictions – can be compared with 'control' locations that were similar in other important respects. However, the need to obtain geo-referenced data at appropriate spatial scales for each variable constitutes a significant, costly constraint to the development of such models, and it is important to evaluate how robust the results are and the degree to which the benefits of developing the models are worth the cost.

This article reviews the practice of modeling human agency in land change in Madagascar in order to synthesize the lessons learned and identify remaining challenges. Examples of spatially explicit models are examined and compared to other types of land-use studies to identify common directions and opportunities for cross-learning. It is important to note that this review draws almost exclusively on the peer-reviewed literature easily accessible to scholars outside of Madagascar. A great deal of very important work has been conducted outside of this domain by Malagasy and other scholars. The paper concludes with a set of recommendations for future models of land change in Madagascar.

SPATIALLY EXPLICIT LAND-USE MODELS: ORIGINS AND ACCOMPLISHMENTS

In 1990, a landmark study was published in Science, bringing satellite remote sensing to bear on the longstanding question of the role of human agency in land change in Madagascar. Green and Sussman (1990) developed maps of the island's humid eastern rainforests from satellite images, which they compared to maps developed three decades earlier.

The resulting map of forest-cover change was then cross-tabulated with maps of population density and topography. The

TABLE 1. Spatial, temporal and thematic characteristics of the main studies reviewed.
*IGN/FTM topographic maps S-47N and S-47S (PERINET and LAKATO),based on aerial photographs from 1957, scale: 1:50,000. L'Institut Géographique National (France)/Foiben-Taosarintanin'I Madagasikara (Madagascar). ** Both studies cite the use of 100-meter, vertically-spaced contour data, the contour interval used in the FTM's 1:500,000 map series. Reference information for the sources not provided in the published work. *** FTM publishes a very popular 1:500,000 maps series, as well as a 1:1,000,000 series, but not a 1:1,500,000 as described in note 29 in Green and Sussman (1990).

	Spatial Extent (km²)	Spatial Resolution (ha)	Temporal Extent (years)	Population		Topographic	
				Variables	Data Source	Variables	Data Source
Gorenflo et al. (In press)	587,000	1,000	1990-2000	density at firaisana level	1993 census, INSTAT	elevation, slope	1:500,000 topographic maps, FTM**
Green and Sussman (1990)	~200,000	81	1950-1985	density at canton level	1966 census, AGM	slope	1:1,500,000 topographic maps, FTM***
Agarwal et al. (2005)	75,000	100	1993	density at firaisana level	1993 census, INSTAT	elevation, slope	1:500,000 topographic maps, FTM**
McConnell et al. (2005)	940	0.09	1957-2000	settlement distance, with and without distance decay	1:50,000 topographic maps, FTM*	elevation, slope	1:50,000 topographic maps, FTM*
Vågen et al. (2006)	476	0.09	1957-2003	density and settlement distance	African Population Database, "existing maps"	elevation, slope	90m Shuttle Radar Topography Mission, NASA JPL

study's main finding of more rapid rates of forest clearance in areas of higher population density has been widely cited in academic publications and in the popular press. The study has also been regularly referred to in policy documents of the country's major donors, such as the United States Agency for International Development, which embraced the paper's recommendation for rapid action to conserve the remaining forest.

Green and Sussman's work (1990) provided no measure of the strength of the relationship between forest-cover change and population density or slope and, therefore, was not a model of human agency. However, numerous efforts have been made to test its conclusions in more rigorous quantitative fashion, including three spatially explicit regression models on subsets of the Green and Sussman study area (Agarwal et al. 2005, McConnell et al. 2004, Vågen 2006) and another for the island as a whole (Gorenflo et al. In press) (see Figure 1, Table 1).

All four studies were able to detect statistically significant relationships between deforestation and variables measuring human population distribution, showing the fundamental population-deforestation relationship to be robust. Green and Sussman's (1990) other main finding was that forest had disproportionately been cleared on flatter land at lower elevations. McConnell et al. (2004), Agarwal et al. (2005), and Vågen (2006) confirmed this relationship as well, with elevation usually exhibiting a slightly weaker relationship with deforestation than population, and slope providing even less explanation.

Confirming the Green and Sussman (1990) findings, however, was not the goal of these spatially explicit models. Rather, they set out to account for the role of these factors so that they could then detect the effects of other factors, particularly those susceptible to public policy. Three of the studies (Agarwal et al. 2005, Vågen 2006, Gorenflo et al. In press) demonstrated that where government has furnished transportation infrastructure, nearby forests were more likely to be felled. The studies also showed that deforestation is muted in wealthier areas and in areas with greater internal disparity of income (Gorenflo et al. In press), and accentuated (i) where soils are poor (Gorenflo et al. In press), (ii) when migrants failed to secure legal access to land (McConnell and Sweeney 2005), and (iii) during periods of political instability (Vågen 2006).

Of particular interest here, the spatially explicit models have begun to deliver on the promise of providing evidence of the effectiveness of biodiversity conservation efforts. Both McConnell et al. (2004) and Gorenflo et al. (In press) were able to provide initial evidence that deforestation rates in protected areas were lower than in comparable nearby areas. These studies have advanced our understanding of the causes of

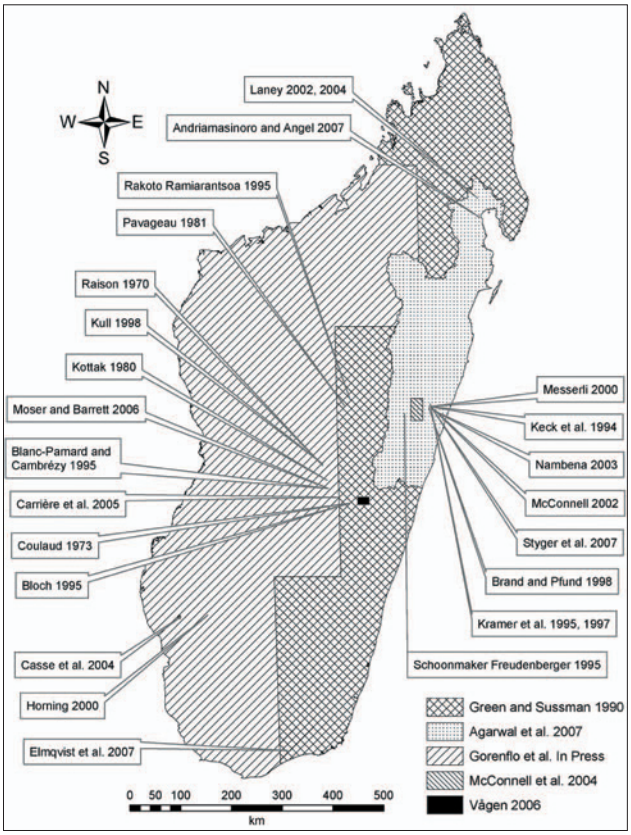

FIGURE 1. Locations of studies mentioned in the text with conterminous study areas.

deforestation, but their results are far from perfect and answer only half of the question. While they tell us that conservation efforts have been able to reduce the loss of forest, many of the relationships they detected are barely statistically significant, leaving considerable room for improvement. Furthermore, they tell us little or nothing about the welfare effects of conservation efforts on the rural populations most directly affected. Fortunately, many other studies of land-use in Madagascar provide valuable lessons for addressing the shortcomings of spatially explicit land-use models (see Figure 1). The bulk of this article constitutes a critical examination of the ways that the spatially explicit studies have treated the factors thought to influence land-use. It employs a broad categorization of factors, following meta-analyses of tropical deforestation (Geist and Lambin 2002, Rudel 2005), agricultural change (Keys and McConnell 2005), and desertification (Geist and Lambin 2004).

This review concentrates on three major categories of factors: Demographic, including the distribution and dynamics of human population in the landscape; socioeconomic, including access to productive resources and the role of local and state institutions; and biophysical, such as landform, soil quality, and climatic factors. Each section begins with a critical review of the approaches taken in the spatially explicit models and then turns to other studies for theoretical and methodological enrichment. Further, these other studies are mined for their attention to the ways that local production systems adapt to the closing of agricultural frontiers, and thus address the consequences of conservation efforts for local people, which are crucial to the sustainability of conservation policies. For the sake of brevity, the studies' depictions of the dependent variable – deforestation – are taken as valid, although there is reason to question their reliability. These issues are discussed in more detail elsewhere (Nelson and Horning 1993, McConnell 2001).

DEMOGRAPHIC FACTORS: POPULATION 'PRESSURE'

The most common factor analyzed in land-change studies is a set of variables meant to represent the pressure local populations, especially resource-dependent people, exert on the nearby landscape (Lambin and Geist 2006). This category encompasses a broad range of processes, such as fertility, settlement patterns, and various forms of migration, but due to the need to amass data amenable to computation, the spatially explicit models have tended to employ fairly crude measures. It is important to examine the studies' methods carefully in order to understand the reliability of their findings, particularly with respect to the representation of population density, and the degree to which they account for spatiotemporal dynamics, and therefore the justification for their causal claims about the relationship between population dynamics and land-use.

POPULATION DENSITY The simplest way to represent human agency in the landscape is to map the spatial distribution of people at some point in time. This is typically done with a population density map that assigns a value to areal units, generally persons / km^2. The source of population data for the Green and Sussman (1990) study was a map published in the *Atlas de Madagascar* (Association des Géographes de Madagascar 1969), showing population density by *canton* (an older colonial small administrative division similar to a district). The data, collected in 1966, were presented in the Atlas in five population-density classes, including one showing areas with more than 100 persons / km^2, yet Green and Sussman (1990) chose to collapse the three highest-density classes into a single class of more than 10 persons / km^2. This simplification bears scrutiny.

The island's total land area is approximately 587,000 km^2, and it had a total population of approximately 12 million people during the study period. Thus, average population density on the island would have been nearly 20 persons / km^2 and urban densities were likely several times higher. With no rainforest remaining near the country's most densely populated areas (e.g. Antananarivo), the higher density regions (i.e. >50 / km^2) were areas in which the deforestation rate was nil, by definition. Including these higher density classes in their study would have led to a very different conclusion about the relationship between population and land-use.

Subsequent, spatially explicit studies employed a variety of approaches to depicting population pressure, although they used continuous variables, thereby avoiding the categorical simplification described above. The broader-scale studies (Agarwal et al. 2005, Gorenflo et al. In press) used similar source maps depicting population density at the *firaisana* level (similar to the *canton*/district level data used by Green and Sussman) derived from the census published in 1993. The population variable in the former study was population count, subjected to a rather complex interpolation to a raster grid that does not correspond to a traditional density value. The latter study employed a sampling approach in which values for population density at nearly 100,000 point locations within *firaisana* polygons were paired with forest cover in satellite image pixels. Meanwhile, the two finer-scale studies on portions of the eastern rainforest edge (McConnell et al. 2004, Vågen 2006) used proximity to village settlements to represent population 'pressure' on nearby forest. In addition to simple Euclidean distance, the former developed more complex surfaces from Voronoi tesselation around village centroids and gravity (potential interaction) models using various distance decay exponents. None of these more complex surfaces produced a stronger relationship with deforestation than simple distance from village centers.

The fact that the four studies all found correlations between their measures of deforestation and population density provides some degree of support for Green and Sussman's (1990) conclusion. However, other studies of deforestation in Madagascar have found mixed results on the association between population density and deforestation rates. For example, a study in the southern dry forests found a non-linear relationship between forest dynamics and a population density variable derived from the LandScan 2001 Global Population Database (Elmqvist et al. 2007). Among four study areas analyzed, the most dramatic loss of forest occurred in a moderately populated area, while forest cover remained stable in the most densely populated areas.

Not all studies of land-use in Madagascar have been concerned solely with deforestation. Many have addressed land-use dynamics when forestland available for conversion to agriculture becomes limited, leading to changes in production systems. There is a substantial body of literature on the conditions under which agricultural production shifts from expansive forms, such as swidden (*tavy*), to more sedentary forms involving greater technology, such as plows or irrigation. One of the foundational works in this vein was Esther Boserup's (1965) work focusing on land pressure as the key to understanding agricul-

tural growth (Chowdhury and Turner II 2006). While the spatially explicit models in Madagascar do not directly build on this literature, other studies do, beginning with the work of French geographers in the 1970s (e.g. Raison 1970, Coulaud 1973).

In his treatise on the Zafimaniry in the south-central highlands, Coulaud (1973) referred to Boserup's (1970) work on the issue of fallow land in African production systems. Working in the waning days of manual cartography, Coulaud wrestled with the various ways of representing population density graphically, comparing maps indicating village locations and number of inhabitants with canton-level choropleth and weighted grid density maps that 'spread' the rural population outside the residential cores of the villages. His calculations led him to conclude that population density in portions of the Pays Zafimaniry surpassed 50 persons / km^2.

Laney (2002, 2004) likewise draws upon this literature in her study of land-use in the Andapa region. She calculates effective population density, based only on land claimed by community members, in order to characterize trajectories of agricultural change. This approach yielded population density in one village of 135 people / km^2. It is noteworthy that in the three spatially explicit models that provided information on population density in persons per km^2 (Agarwal et al. 2005, Vågen 2006, Gorenflo et al. In press), the densities tended to be rather low compared to the densities calculated in other studies (Coulaud 1973, Keck et al. 1994, Kull 1998, Laney 2002, 2004, Elmqvist et al. 2007).

TEMPORAL DIMENSIONS AND CAUSAL CLAIMS It is one thing to compare a map of land-use with a map of population density and detect a correlation. It is another thing to establish a causal linkage between population growth and deforestation. Unfortunately, the conflation of correlation and causation is an all-too-common problem in land-change studies generally (Kaimowitz 1997, Lambin 2000, Millington et al. 2007).

Having effectively aggregated most of the island's population, including most city dwellers, next to the forest and finding higher rates of deforestation in these more populous areas, Green and Sussman (1990: 212) conclude "the major threats to the remaining forest are driven by subsistence needs." This claim is made without evidence of a causal relationship; rather it is substantiated by reference to three non-peer-reviewed sources. The authors apparently assumed that if deforestation is happening close to large numbers of people, then those people must be responsible; and since they are overwhelmingly subsistence farmers, they must be clearing forests. Yet their data contain neither information about population dynamics, nor on the land-use practices of the people in the landscape.

Agarwal et al.'s (2005: 123) model commits a similar – albeit milder – conflation of correlation and causation, stating "Increased population pressure increased the chances of forest degradation." The statement suggests that a change in population was observed to have led to a change in the likelihood of deforestation, when in fact both the population density and forest cover variables represent single points in time, and the analysis simply detected a statistically significant correlation in the form of a spatial coincidence of their patterns; no process was actually observed. The authors do refer to three historical maps to derive suggestions about demographic trends over the past century, but these dynamics did not figure in their regression analysis, due to lack of data. The only spatially explicit model that did include a variable representing population dynamics was Vågen (2006), who tested the relationship between deforestation and change in decadal population density depicted in the coarse-resolution (1-km^2 pixel) African Population Database (APD) (Deichmann 1994). However, the spatial interpolation of population distribution in the APD maps is driven by quite coarse proxy variables that are unlikely to capture actual demographic processes at such fine scales. It is not surprising that this variable failed to relate well with observed changes in land cover.

Other land-use studies in Madagascar have addressed this issue more directly, sometimes with contradictory results. In seeking to shift responsibility for deforestation from poor peasants to colonial logging enterprises, Jarosz (1993, 1996) drew on a report of the French *Institut national d'études démographiques* to conclude that much of the destruction of the country's eastern rainforest occurred during a period when population may have been stable or even declining. A case study of forest dynamics in the southwestern part of the country (Casse et al. 2004) was able to detect a positive, albeit weak and indirect, relationship between increase in the number of inhabitants of six villages over a decade and increases in distance between those villages and the nearest available forest. Kull (1998) used district- and *canton*-level figures from various sources to document strong population growth in a southern highlands study area throughout the 20th century, which he qualitatively related to agricultural expansion depicted in aerial photographs across four decades.

Keck et al. (1994) tackled the agricultural intensification question in an eastern rainforest study region, also drawing on the agricultural change literature (e.g. Boserup 1965, Pingali et al. 1987). They evaluated pressure on the swidden system using the R-value measure of cultivation frequency (Ruthenberg 1976) and concluded "the region is on the verge of evolution to a short fallow farming system" (Keck et al. 1994: 14). They also concluded that the change is associated with population increase, although the source of their estimate of 3.5 % annual population growth is not cited. Laney (2002, 2004) likewise focuses on cropping frequency in her differentiation of farms that had modified their production systems in ways that enabled them to maintain or increase levels of consumption from others that followed involution and stagnation trajectories (Geertz 1963).

It is significant that population mobility, or migration, is all but absent from the spatially explicit models reviewed here, despite its important role in many parts of the island over the past century. McConnell et al. (2004) suggest that migration may have accounted for some of the false positive residuals of their logistic regression model of deforestation, but did not attempt to construct a variable to test this hypothesis. Other studies have documented the importance of a variety of processes, including voluntary migration, such as the settlement of the 'Vanilla Triangle' in the northeast after foreign coffee and vanilla producers discovered the region's rich soils (Laney 2002), and cyclical abandonment and recolonization in the south (Elmqvist et al. 2007). In some instances, government encouragement, or even coercion, has led to resettlement, particularly to move populations away from natural forests (Coulaud 1973). Migration continues to shape land-use throughout the island, including rural immigrants driven by land pressure in their home areas to search for agricultural land elsewhere, or for employment in farming, mining, or urban enterprises (Schoonmaker Freudenberger 1995, Durbin et al. 2003, Casse et al. 2004, Kull 2008).

SOCIOECONOMIC AND INSTITUTIONAL FACTORS

Once the distribution and dynamics of the population have been accounted for, land-use studies generally turn to a number of interrelated factors that shape land-use practices. These factors range from characteristics thought to shape the behavior of the inhabitants, to the various institutions that constitute the social milieu in which land-use takes place, be they clan or lineage groups, village or other community structures, government agencies, or non-government organizations (Chowdhury and Turner II 2006).

TRANSPORTATION The presence of transportation infrastructure, particularly roads, is probably the most commonly studied manifestation of government influence in land-change models globally, and deforestation analyses in particular (Nelson and Hellerstein 1997, Kaimowitz and Angelsen 1998, Geist and Lambin 2001, Rudel 2005). Such infrastructure commonly serves as a proxy for the ability of local people to access both land for conversion and / or extraction and technology and information. Three spatially explicit models addressed the role of transport infrastructure in shaping land-use. Vågen (2006) and Gorenflo et al. (In press) detected significant relationships between deforestation and distance from roads and paths digitized from topographic maps published by *Foiben-Taosaritanin'i Madagasikara* (FTM), Madagascar's mapping agency. Agarwal et al. (2005) developed a simpler binary variable representing presence / absence of transportation routes (footpath, rough track, motorable track, primary road, and railroad) from FTM maps, and likewise found this variable strongly related to deforestation.

None of the spatially explicit models includes a variable representing change in transportation infrastructure, making it difficult to assess causality. The FTM map series depicts the transport infrastructure in its current state to the degree possible, but maps are revised infrequently. Metadata on these revisions are too brief to enable the user to know at exactly what point the roads and paths may have conformed to the representation in any given published map. Little major road development has taken place in Madagascar since 1957, although major upgrades have been made in some locations. Elsewhere, degradation is the norm, with temporary and longer-term interruptions inhibiting physical connections to markets and, more generally, discouraging farmers from risking the investment of scarce resources in cash crop production (Schoonmaker Freudenberger 1995). Such dispersed and intermittent disruptions pose a substantial challenge for modeling.

A further challenge is that in many parts of the country the existence of a road is not a reliable proxy for market demand, since sales of agricultural produce depend on the few people who are able to operate trucks to transport goods from rural areas. One study of deforestation (Casse et al. 2004) oddly ruled out transportation costs as a useful explanatory factor, suggesting that all farmers receive the same farmgate price, although prior work suggests large differentials in prices depending on a farm's location within the precarious road network (Bernier and Dorosh 1993, Karaska et al. 1996, Fafchamps and Minten 2002). New econometric work on the impact of hypothetical new roads has provided a valuable foundation for the empirical treatment of such factors in future land-use models, such as Jacoby and Minten's (2008) canonical model for farmers' willingness to pay for new roads.

SOCIOECONOMIC STATUS For the most part, spatially explicit studies have treated people in the landscape as homogeneous in all respects other than their spatial distribution, failing to take account of their relative access to productive resources. One exception is Gorenflo et al. (In press), who made use of data from The World Bank on consumption-based welfare at the *firaisana* level (Mistiaen et al. 2002). With this data, they were able to show that deforestation rates tend to be lower in wealthier areas and in areas with greater internal disparity of income.

The relative availability of the resources necessary for farming is traditionally central to agricultural change studies. A series of studies conducted by researchers affiliated with Cornell University in the 1990s on rice production in Madagascar focused on farms' endowments of land, labor, and capital. Bernier and Dorosh (1993) found that household characteristics, such as cattle ownership, and various measures of educational attainment showed strong relationships with fertilizer adoption. This group also analyzed the likely effects of liberalization in rice marketing, finding that while higher prices would spur wealthier farmers to increase production, they penalized the majority of farmers who were producing below subsistence level and had to purchase rice (Barrett and Dorosh 1996).

Subsequent work focused on the adoption of a suite of irrigated rice-growing techniques known as the System of Rice Intensification (SRI). Barrett et al. (2004) used regression models to confirm that better endowed farms, in terms of land and labor, as well as experience and the means to apply manure, derive the greatest benefit from the adoption of SRI. They found that while all farmers stand to benefit from adopting SRI, less well-endowed farmers choose not to because, for them, the variability of SRI production outweighs the potential benefits, creating a strong disincentive.

Later, Moser and Barrett (2006) detected statistically significant relationships between initial SRI adoption and landholdings, especially lowlands suitable for irrigated rice production, and several other measures of 'liquidity' (e.g. off-farm income, reliance on agricultural day labor). They found that the larger, diversified farms producing wheat and dairy products were less likely to suffer from seasonal bottlenecks, enabling them to invest in SRI. Adoption rates were significantly lower among households forced by land shortage to sell their labor to other farms.

LAND TENURE In farming communities, wealth is often closely linked to access to land, either to convert land for agricultural production or to utilize existing cropland. It is therefore no surprise that this issue has figured prominently in land-change studies in Madagascar, although the spatially explicit models have barely begun to address the issue. McConnell et al. (2004) found some evidence in their regression residuals to support the previous findings of Schoonmaker Freudenberger (1995), who reported the clandestine clearing of fields inside the Maromizaha forest by residents unable to obtain land through the admixture of customary and state authorities.

Access to land resources in Madagascar is traditionally governed by local customary institutions reflecting the initial settlement of the landscape and the community's subsequent political history (Keck et al. 1994, Schoonmaker Freudenberger 1995, Laney 2002, McConnell 2002, Raik 2007). The French colonial government introduced a system of formal land titling in the early 20th century; however, Keck et al. (1994) found

only 5% of the farmers in their study held formal title to their land, and nationally it has been estimated that the rate is less than 10%, leaving the remainder under customary control (Montagne and Bertrand 2006).

The slow pace of the formalization of land rights was long thought by economists at The World Bank and elsewhere to pose a major obstacle to agricultural development in Africa. Case studies in Madagascar, however, have not always supported this thesis. For example, a World Bank study in the area adjacent to the Mantadia National Park (Keck et al. 1994) concluded that lack of access to markets, for both inputs and farm produce, were at least as important as formal land rights in hindering intensification. Likewise Randrianarisoa and Minten (2001) demonstrated that increasing formal land titling is unlikely to have a significant effect on improved agricultural performance in Madagascar, compared to other factors.

Some land-use studies have shown the importance of inter-household interactions regarding access to land. For example, Laney (2002, 2004) highlighted the significance of the annual arrangements for borrowing and renting land among families in the Andapa region for differentiating household land-use intensification trajectories. Elsewhere, Kull (1998) highlighted the salience of renting and sharecropping arrangements that have shaped land-use change in the central highlands in past decades. Interestingly, Keck et al. (1994) found these arrangements absent in the eastern rainforest region they studied. Bellemare and Barrett (2003: 14) developed a model of a form of sharecropping found in Madagascar called 'reverse share tenancy' in which poor households rent out land to richer tenants on shares. The authors hypothesize that "as property rights become more secure, reverse tenancy sharecropping will tend to disappear, with poorer land owners benefiting from reduced … inefficiency as a result of endogenously changing agrarian contracts" and suggest that property-rights enforcement will be important to redress this problem.

STATE AND LOCAL INSTITUTIONS Providing formal title to land is one way the state intervenes in the question of access to land. No less important, though, is the state's claim to all remaining land. The Malagasy state has asserted exclusive rights to the island's forests since at least the 1800s, and under the French regime these lands were mapped and various levels of protection ascribed, ranging from very strict (e.g. Strict Nature Reserve) to less restrictive (e.g. classified forests). Together, these various forms of state exclusion accounted for about half of the island's 13 million hectares of standing forests by the end of the 20th century (Direction des Eaux et Forêts 1996).

Two spatially explicit models have addressed the success of these protection efforts. McConnell et al. (2004) found some evidence of the success of formal restrictions in maintaining the integrity of core forest blocks in a national park and a special reserve. Gorenflo et al. (In press: 15) were able to derive an actual estimate for the amount of protection afforded: "Other factors held constant, the presence of a protected area will on average decrease the probability of deforestation by 5.2% per decade. In relative terms this translates into about 61.5% reduction [sic] below the base deforestation rate for Madagascar as a whole".

The state's claims to land have not gone uncontested by local populations, and Vågen (2006) attributes a period of rapid deforestation in the 1990s to the "turbulent political situation" at that time, as the local population took advantage of lax enforcement (Vågen 2006: 223). Other studies have elaborated similar themes, relating the burning of grasslands and forests in defiance of, or in protest against, state land-use restrictions (Jarosz 1993, 1996, Kull 2004). These actions have sometimes been explained in terms of the desire of rural people to ensure the persistence of cultural value systems. For example, in the highlands, Bloch (1995) showed how highly the Zafimaniry value the creation of 'openness' in landscapes, while Kull (2008) explicates the seemingly counter-intuitive Betsileo notion of 'saving land' by improving it through cultivation. Similar institutional factors relating to production systems have been shown to significantly affect land-use in Madagascar. For example, Bernier and Dorosh (1993: 46) found individual respondents' fertilizer use to be highly correlated with a variable describing the proportion of farmers in the region also using fertilizer. They offer two possible interpretations of this 'neighborhood effect': It may demonstrate intra-communal interaction in "the quality of water control in an irrigated perimeter shared by many farms"; alternatively, it may be related to a government fertilizer promotion program. Subsequent studies found similar factors to be important correlates of land-use: Variables describing social conformity, 'learning effects' (learning from other farmers), membership in farmer organizations, and extension services were all found to be significantly related to the adoption of SRI (Moser and Barrett 2006). Other studies in Madagascar have amply demonstrated the importance of social capital in the form of non-monetized transfers of wealth among farm families (Bernier and Dorosh 1993, Karaska et al. 1996) and information exchange among agricultural food products traders (Fafchamps and Minten 2002).

While the maintenance of local customs offers some explanation of land-use, their deterioration has also been cited. For example, Bloch (1984) showed how increasing pressure on land resources and worsening terms of trade led to the breakdown of cultural institutions such as reciprocal labor exchange, which had been crucial to the construction and maintenance of shared irrigation infrastructure. This erosion of local institutions has been linked to a more general social crisis with land-use implications, including banditism and cattle rustling (Kottak 1980, Pavageau 1981, Bloch 1984). The threat of losing proceeds to theft is a strong disincentive for both livestock production and the production of agricultural surpluses (Vérin 1992, Karaska et al. 1996). Econometric work has begun to pave the way for the incorporation of rural insecurity in land-use models, quantifying the relationship between cattle rustling and other crimes and geographical isolation, as measured by distance from urban centers and low population density (Fafchamps and Moser 2003).

Expansion of the country's protected area network under the Durban Vision and the possible leasing of over a million hectares of land for export farming create a strong need for rigorous analysis of the effectiveness of policy options. The task is all the more complex as the range of forest management regimes has recently expanded to include a range of contractual arrangements with local communities (Antona et al. 2004, Montagne and Bertrand 2006, Raik 2007).

These circumstances may seem to pose an insurmountable level of complexity, but fortunately the literature in common-property resources (Ostrom et al. 2002) offers substantial guidance, including sets of 'facilitating conditions' (Wade 1994)

and 'design principles' (Ostrom 1990) for effective governance of common resources (Agrawal 2002). Several studies of land-use in Madagascar have applied these frameworks in the comparative analysis of forest governance regimes, including Elmqvist et al. (2007) who compared four sites in the southeast, finding the worst conditions in the area with the least coherent enforcement of access rules. Two studies also applied the standardized protocols developed by the International Forestry Resources and Institutions (IFRI) research program (Ostrom and Wertime 2000), including Horning (2000) comparing forests in the southwest and McConnell and Sweeney (2005) comparing forests in the east coast and central highlands. The IFRI approach specifies questions related to the physical aspects of the resource to which access is being managed (the forest), the particular uses for which the forest is managed, the characteristics of the user groups, and the rules that govern those uses. In these studies, forests managed for multiple products through collaboration among user groups to establish and enforce rules were found to be achieving greater success.

BIOPHYSICAL FACTORS

While it might be expected that biophysical factors would play prominent roles in studies of land-use change, this has not generally been the case globally (Geist and Lambin 2002, 2004, Keys and McConnell 2005). Land-use studies in Madagascar have mainly focused on topography, following Green and Sussman (1990). According to their Science article, their slope map was derived from 1:1,500,000-scale topographic maps published by FTM in 1980, although no other reference to this map series has been located. The subsequent spatially explicit models employed higher precision data sources, such as NASA's Shuttle Radar Topography Mission (SRTM) at 90-m pixel resolution (Vågen 2006) or contour data from FTM maps, either 1:500,000 scale (Agarwal et al. 2005, Gorenflo et al. In press) or 1:50,000 scale (McConnell et al. 2004) (Table 1). Again, the confirmation of the relationship between deforestation and topography lends confidence to the robustness of the relationship. The findings also provide some nuance to the understanding of the dynamics of the population-pressure variable; they quantify the easily observed pattern of settlement along perennial watercourses, which are by definition at lower local elevations.

Further experimentation with other topographic variables has yielded mixed results in explaining land-use. Nambena (2003) used higher order topographic variables (relief form and hillside exposures) derived from a digital elevation model to explain the distribution of intensive garden plots (*tanimboly*) in a study area in a mountainous region in eastern Madagascar. However, in the highlands, Barrett et al. (2004) were unable to detect a relationship between a plot's location in the topo-sequence and the benefits of SRI adoption.

Some studies have addressed the related issue of soil fertility. For example, Barrett et al. (2004) detected a significant effect of a binary soil quality variable on the benefits of SRI adoption. Other studies have provided detailed descriptions of farmers' responses to declining soil fertility resulting from swidden farming (Kramer et al. 1995, 1997, Brand and Pfund 1998, Messerli 2000, Nambena 2003, Carrière et al. 2005, Vågen 2006, Vågen et al. 2006a, 2006b, Styger et al. 2007). Such studies provide strong foundations for the incorporation of these processes in future models.

Weather conditions, and other biophysical factors, occasionally appear as explanatory factors in quantitative studies, but meteorological data are spatially and temporally sparse in Madagascar. To date, these factors have been treated through regional dummy variables (Barrett et al. 2004, Gorenflo et al. In press), or as qualitative, contextual factors (Kull 1998, Elmqvist et al. 2007). Improved treatment of such processes will be crucial to the development of improved models of human agency.

CONCLUSIONS AND RECOMMENDATIONS

The first decade of the new millennium has produced a suite of spatially explicit models of human agency in land change in Madagascar that have tested the findings of the landmark work of Green and Sussman (1990). These models have quantified the population-deforestation relationship – not as a goal, but as a step toward greater understanding of the role of human agency in land change. Clearly human presence must be accounted for in order to begin examining how those people came to be there, how and why they used the land once they arrived, and how that land-use might be shaped by public policy aimed at balancing their welfare with the conservation of the island's precious biodiversity. The increased sophistication of the models has come at no small cost in data collection and analysis, and we have to ask if these efforts have lived up to their promise of better judging the effects of policy actions aimed at conservation and improved human welfare.

This review suggests that a positive, albeit modest, response may be warranted. The models have begun to detect the 'signal' of policy impacts against the 'background' of what might have been expected in the absence of such policy (Ferraro and Pattanayak 2006). By first accounting for the effects of settlement location and topography, two spatially explicit models (McConnell et al. 2004, Gorenflo et al. In press) suggest that deforestation has been slower in protected areas than might otherwise have been expected, given trends in similar areas. Of course, such tests of effectiveness are imperfect, as no true control group exists to definitively show what would have happened in the absence of such protection. The spatially explicit models have yet to address the implications of these policies for human welfare, especially the local populations directly affected.

LIMITATIONS OF THE CURRENT SET OF MODELS

The findings synthesized here are limited in their representation of the vast extent and diversity of the country and its people. The models reviewed concentrated on swidden systems associated with deforestation and on irrigated rice production, largely ignoring other aspects of the island's mix of agro-sylvo-pastoral land-uses. Livestock production, for example, has tended to appear in the econometric models as an explanatory variable impacting the land-use activity of interest – irrigated rice production. However, such an approach assumes that these practices are analytically separable when, in fact, the two are outcomes of the same decision-making process.

An important land-use dynamic that deserves further attention in spatially explicit models is the reforestation of the island's central highlands. Although several studies have documented increases in tree cover in various parts of the island (Rakoto Ramiarantsoa 1995, Kull 1998, Elmqvist et al. 2007), this outcome has rarely appeared as the dependent variable

in spatially explicit models (cf. Vågen 2006). Interestingly, had the landmark Green and Sussman (1990) study not restricted its dependent variable to exclude all but humid forest, it might well have detected an increase in tree cover around the capital, thereby upsetting the neat relationship between population density and deforestation.

In addition, the studies reviewed here were conducted at quite different spatial scales (see Table 1), and we must be cognizant of the fact that relationships between land-change outcomes and various social and biophysical factors usually change with the scale of the analysis (Walsh et al. 1999, Kok et al. 2001, Veldkamp et al. 2001, Evans and Kelley 2004). The issue has been directly addressed in the case of Madagascar by Laney (2002, 2004), demonstrating how variables explaining land-use trajectories at farm level do not necessarily apply at village level, and arguing for close attention to such 'scalar dynamics.'

Finally, this review is limited in its temporal scope, neglecting most of the period of human habitation of the island. At the same time that scientists have been exploiting remote sensing to elucidate recent human-environment interactions in Madagascar, other researchers have been applying paleoecological tools to test long-held notions of the longer-term imprint of humans on the island's flora and fauna. The discovery of grass pollen and charcoal deposits in lake sediments predating the arrival of humans has undercut the conventional view holding people responsible for clearing large portions of the island's 'original' forest cover (Burney 1987a, 1987b, 1997, Gasse and Van Campo 1998, 2001, Burney et al. 2004). These findings are reinforced by botanical work demonstrating that the grasslands of Madagascar's central highlands are quite ancient, easily predating human settlement (Bond et al. 2008). Other anthropological work has attempted to parse the role of direct and indirect human impacts (i.e. hunting and habitat change, respectively) in the extinction / extirpation of non-human primates in late pre-historical Madagascar (Godfrey and Irwin 2007). The extension of land-use models back in time offers promise of understanding the legacies of these prior land-use dynamics. This is important because the projections of land-use models are often limited by non-stationarity; that is, the processes responsible for land change vary through time, such that variables assume different explanatory power in different time periods (Aspinall 2004).

RECOMMENDATIONS A number of recommendations emerge from this review of the existing set of spatially explicit land-use models, and from the broader literature on land-use in Madagascar.

Accounting for the presence of the human population will continue to be a *sine qua non* for land-use models, and the development of more reliable demographic data for Madagascar is imperative. Particularly urgent for broader scale studies are the reconciliation of the 1966 and 1993 population data, and the development of reliable data for preceding and intermediate periods. At finer scales, future models should be explicit about what land base is being considered in the analysis of demographic processes – whether it includes land currently under production only or also fallow land and / or 'virgin' land (i.e. effective population density). The consideration of land pressure in swidden systems can usefully be based on the frequency with which parcels are cropped (i.e. R-value), and a family's land endowment should be considered in the context of the number of people that land is expected to support and the proportion of them able to actively participate in farming (i.e. the dependency ratio).

To the degree that land-use models are aimed at contributing to improved policies, though, it is essential that they take into account the cultural, social, and political factors most amenable to policy, particularly those governing access to land, including both formal and informal arrangements for loan, rental, sharecropping, etc. The variety of institutions operating at different scales and through time poses a serious challenge, but it is not insurmountable. Future studies should avail themselves of tools that facilitate the systematic analysis of issues such as land tenure and the management of common-property resources, such as the IFRI protocols.

Relatively recent developments in agent-based, or multi-agent system, models that accommodate the behavior of individuals and groups (e.g. families, villages, state agencies) (e.g. Parker et al. 2003) could be helpful. Although not a land-use model, a useful example for Madagascar is Andriamasinoro and Angel's (2007) simulation of the artisanal mining of ultrapure quartz. The authors use a set of agents (local quartz buyers, conveyors, community, and state) who interact in an environment that includes the quartz lode, collection and grinding locations, and the export ports.

A reliable multi-temporal database of the country's roads must be developed for accurate assessment of the role of transportation infrastructure, one of the most important government interventions, on human agency in land change. The necessary information on the nominal state of infrastructure is held in FTM's archives, but considerable investment will be required to put that information into digital formats required for spatially explicit modeling.

Better data on land-use and land cover at different points in time is absolutely indispensable. Efforts to catalogue and make available all existing satellite imagery should be bolstered, and the development of well-documented land-use and land cover data from the country's significant aerial photography archive should be a high priority. Soil fertility and climatic factors could also offer improved explanation, perhaps building on the 1:200,000 *Carte des ressources en eaux* series developed by the *Centre National de Recherche sur l'Environnement*. However, the costs of developing appropriate soils data will not be negligible, as soil conditions tend to be quite heterogeneous, requiring intensive (and therefore costly) ground collection to appropriately capture meaningful variation.

While the past decade has seen significant progress in modeling land-use in Madagascar, the contributions to improved policy have been modest. Demonstrating the effectiveness of conservation policy (i.e. protected areas) is crucial to securing and effectively using scarce financial resources. Parsing the effects of different forms of protection (e.g. National Park or Special Reserve) will provide even better guidance. A crucial area for improvement is in assessing the human welfare impacts of conservation policy. Many of the econometric models discussed above set out specifically to examine these issues, and the integration of spatially explicit and econometric approaches is desirable. Caution must be exercised, however, to ensure that the models do not become so complex that their methods are inaccessible to policy makers and stakeholders.

The sorts of improvements outlined above may enable future models to better contribute to the formulation of policy that can balance protection of the island's biodiversity with securing the livelihoods of the Malagasy people. However, until such time as verification and validation of model results are achieved, the model outputs should be treated with caution. A model inter-comparison effort involving scientists, policy makers and stakeholders would be extremely valuable in ensuring that future modeling efforts provide results that are reliable, robust and relevant.

POSTSCRIPT

Since this manuscript was initially submitted, news reports have cited the Ravalomanana government's negotiations to lease large tracts of farmland to Daewoo as a *cause célèbre* in the political turmoil in early 2009.

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EDITORIAL NOTE

The recent political instability in Madagascar is having far-reaching consequences beyond the social and cultural aspects. Due to an imminent lack of governance and responsibility, several protected areas, such as Masoala and Marojejy National Parks, have been targeted by increased illegal logging and pillaging of other natural resources including rare and endemic plant and animal species for export to other countries. This has been reported by several national and international news press and other medias. For more details please refer to http://www.illegal-logging.info/item_single.php?item=news&item_id=3247&approach_id=18

Voices from the marsh: Livelihood concerns of fishers and rice cultivators in the Alaotra wetland

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ABSTRACT

Lake Alaotra is the largest lake on Madagascar and is a centre of rice and freshwater fish production. The lake and its wetland also provide important habitat for endemic wildlife. In 2003 the Alaotra wetland system was designated a Ramsar site and has subsequently been recognized as an official protected area by the Government of Madagascar. While community-based conservation initiatives have led to active involvement of some lakeside communities in the conservation of the aquatic system, wetland destruction continues. The extent to which individuals within these communities perceive the protection of the environment as their priority remains unclear. The current study collected socio-economic data from fishers and rice cultivators living in Anororo, a small town situated on the west coast of Lake Alaotra. Results suggest that livelihood security within these groups is limited. While they hope for better protection of the environment their primary concern is for external investment in their professions. These results highlight the need for solutions to be found to meet current livelihood priorities while efforts continue to conserve natural resources for the future.

RÉSUMÉ

Le lac Alaotra est le plus grand lac de Madagascar et il est un centre de production rizicole et piscicole. Le lac qui a une superficie de 20,000 ha et les zones humides qui l'entourent constituent aussi un habitat important pour des espèces fauniques endémiques. Les initiatives de conservation communautaire impliquant des communautés riveraines dans les actions de protection du système aquatique n'empêchent pas la destruction des zones humides. L'extension des rizières dans les marais de la Nouvelle Aire Protégée (NAP) que des gens de ces communautés pratiquent, montre que ceux-ci perçoivent mal l'importance de la protection de l'environnement, et qu'ils sont loin de pouvoir la considérer en tant que priorité. L'étude actuelle est basée sur des données socio-économiques récoltées auprès de pêcheurs et de cultivateurs d'Anororo, un grand village situé sur la rive ouest du lac Alaotra. Les résultats montrent que la sécurité alimentaire de ces groupes sociaux est limitée car s'ils souhaitent une meilleure protection de l'environnement, leur première inquiétude les incite à investir dans leurs professions. Ces résultats soulignent la nécessité de trouver des solutions pour assurer les moyens de subsistance tout en développant la conservation des ressources naturelles pour le futur. La valorisation de l'utilisation durable des ressources naturelles lacustres et palustres de la NAP sous forme d'activités artisanales génératrices de revenus familiaux améliorera cette subsistance. Elle sera à proposer dans le Plan d'Aménagement et de Gestion Environnementale et Sociale, à élaborer et à adopter prochainement au niveau de chacune des seize communes périphériques du lac dont celle d'Anororo.

KEYWORDS: Lake Alaotra, wetland, Madagascar, livelihood, fisher, rice cultivator.
MOTS CLEF : lac Alaotra, zone humide, Madagascar, subsistance, pêcheur, riziculteur.

INTRODUCTION

Lake Alaotra covers an area of 20,000 ha in the central highlands of Madagascar (E48°26', S17°31') (Andrianandrasana et al. 2005) (Figure 1). Over 550,000 people live along its shores (Plan Régional de Développement 2003), most of whom practice fishing or rice cultivation as their primary livelihood (Blanc-Pamard 1987, Ranarijaona 2007).

Until recently the Lake Alaotra wetland has been viewed as the 'rice bowl' of Madagascar producing the largest and highest quality harvests on the island (Bakoariniaina et al. 2006). However, due to erosion from the surrounding hills siltation of the rice fields has resulted in a 40 % decline in crop productivity in recent years (Wright and Rakotoarisoa 2003, Bakoariniaina et al. 2006). Similarly, while the lake is an important source of freshwater fish for the island, catches appear to have declined from an annual high of 4,000 tons in the 1960s (Pidgeon 1996) to approximately 2,000 tons per annum in 2003 (Razanadrakoto 2004). Sedimentation and wetland conversion to agricultural land has contributed to the reduction of Lake Alaotra to 20 % of its former size (Bakoariniaina et al. 2006).

Lake Alaotra is also recognized as a centre of freshwater biodiversity within Madagascar. The 23,000 ha of wetland bordering the lake supports the Critically Endangered Alaotran gentle lemur (Andrianandrasana et al. 2005)

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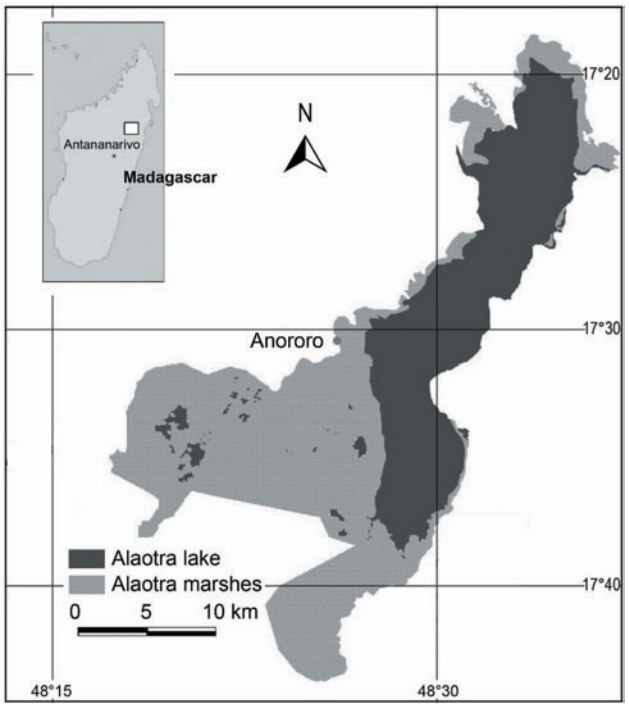

FIGURE 1. Map showing Lake Alaotra and location of the study site, Anororo.

Hapalemur alaotrensis (Groves 2005). At least six endemic species of wildfowl have been observed at the lake as well as six species of endemic fish (Andrianandrasana et al. 2005). In an attempt to conserve the wildlife and the lake as a functioning ecosystem the Durrell Wildlife Conservation Trust launched an education and awareness campaign in lakeside communities in 1996 (Durbin 1999). In 2003 Lake Alaotra was designated a Ramsar site to provide a framework for protecting the remaining wetland (Ramsar 2007). More recently, the Government of Madagascar has classified the lake as a protected area in 2007 (Arrêté N° 381-2007 / MINENVEF/MAEP).

Since these initiatives were launched tenure rights to over 35 % of the existing marsh has been transferred from government to local community institutions to manage (Andrianandrasana et al. 2005). Local traditional laws (*dina*) have been established to ban wetland burning and to regulate fishing activities and wetland use (Andrianandrasana et al. 2005). A two-month closed fishing season has been strictly enforced since 2002 to try to conserve fish stocks (Andrianandrasana et al. 2005).

Despite these efforts the wetland vegetation which surrounds the lake remains under threat through burning of the vegetation during the dry season (Ranarijaona 2007). In 2004, the area of wetland was reduced to almost 47 % (10,816 ha) through burning during the dry season (Table 1). This vegetation provides important nursery grounds for fish, habitat for *Hapalemur alaotrensis,* and creates an important barrier to siltation and pollution (Andrianandrasana et al. 2005). Multiple reasons have been suggested to explain why people burn the marsh, including a desire for more agricultural land for rice cultivation (Ralainasolo et al. 2006); to aid in poaching *H. alaotrensis* (Mutschler et al. 2001)*;* to provide space to set fishing nets within the vegetation (Andrianandrasana et al. 2005); and as a form of political protest (Razanadrakoto 2005). The most recent evidence suggests that people are burning the wetland to access the introduced Asian snakehead (*Channa maculata*), a fish that buries itself in the mud under the vegetation during the dry season (Ranarijaona 2007, Copsey et al. In press).

Whether or not wetland burning is motivated by the need to overcome immediate resource limitations (e.g. fish for food) is currently unknown. Fundamentally, little information exists on what local livelihood concerns are and how these correlate with externally-influenced biodiversity conservation goals. The current case study was conducted to begin to address this gap, gathering information directly from lakeside people on the socio-economic realities of life and documenting their main concerns for the future. The data will inform ongoing efforts to conserve Lake Alaotra and its surrounding wetlands and help to balance this goal with a commitment to address immediate livelihood concerns.

METHODS

The study was conducted over an eight-week period, from May to July 2007. It was based in the *fokontany* (smallest administrative unit in Madagascar) of Anororo, on the west coast of Lake Alaotra. According to a census published in 2004 (Plan Communal de Développement), Anororo has a population of approximately 8,000 people. Based on the traditional division of the Alaotra marshes, Anororo also possesses 9,850 ha (42.8 %) of the remaining 23,000 ha of marsh within its boundaries (Andrianandrasana et al. 2005).

Data collection began after an initial 10-day period in the village, providing an opportunity for the leadauthor and townspeople to become familiar with one another. Data were collected using two methods: Semi-structured interviews and questionnaires. Purposive sampling (Bernard 2006) was used to identify individuals for the semi-structured interviews. Interviews were conducted in Malagasy, the second author translating between Malagasy and French for the lead author. In total 27 semi-structured interviews were conducted. The majority of these (n=23) were with fishers; fishers who also grow some rice (fishing-cultivators); or rice cultivators. The remaining four semi-structured interviews were conducted with a butcher, shopkeeper, female fish collector and a female artisan from Anororo. In addition, 10 interviews were conducted with wholesale rice buyers in Anororo to ask them about prices they offer to farmers throughout the year for their rice harvests.

A questionnaire was then designed to test whether the views expressed during interviews reflected those of the townspeople in general and also to obtain more quantitative information on rice production, fish catches and the amount of each that are sold. Questionnaires were written in French, translated into Malagasy and then back-translated to French to check for any misunderstandings caused by language. Questionnaires were administered by the second and third authors, literate respondents being permitted to read the questions themselves. Spatially and temporally structured sampling identified respondents for the questionnaire. One-hour sampling time

TABLE 1. Estimated area of marsh burnt 2000-2004.
Data acquired by estimating area of marsh burnt during previous year's dry season. [a]Data from Andrianandrasana et al 2005; [b]Data from Durbin 2006.

Year	2000[a]	2001[a]	2002[a]	2003[a]	2004[b]
Marsh area burnt (ha)	7,300	4,430	392	2,500-2,600	10,816
% total marsh area (23,000ha)	31.7	19.3	1.7	>10	47

frames were randomly selected each day, and during these periods all rice cultivators who entered the town from the single track leading from the rice fields into the town were interviewed. For fishers we randomly selected one-hour sampling time frames and locations, as fishers could land their catches at six main locations around the town. In total, 122 questionnaires were conducted face-to-face with 122 male adult fishers, rice cultivators and fishing-cultivators; approximating 5 % of the adult male population in Anororo (Plan Communal de Développement 2004).

RESULTS

CURRENT LIVELIHOOD CONCERNS. Variability in fish catches and prices: Mean maximum daily fish catch was 11.4 kg ± 1.9 (n=82) compared to 3.6 kg ± 0.9 (n=82) for the mean minimum caught by fishers in Anororo over the seven days prior to completing the questionnaire. According to fishers interviewed a range of factors contribute to this variation. They identified seasonal changes in water temperature and water levels as factors which influenced fish catches, and also short-term variations in the position of the moon, presence or absence of cloud cover and rainfall. They also recognised the type of fishing method employed to influence fish catches. A total of 76 % of questionnaire respondents possessed either fish traps (*vovo*) or fishing nets (*harato*). One fisher interviewed stated that particular environmental conditions can influence the effectiveness of the fishing technique employed. According to him when the sky was clear and the moon bright at night the fish would not enter the traps.

Fishers also reported differences in the price they can obtain for the same quantity of fish. According to one fisher interviewed the price difference is partly determined by the species of fish caught. The introduced Common carp (*Cyprinus carpio*) is the most expensive species (US$ 1.5/kg) and species such as tilapia (Cichlidae) and Asian snakehead (*Channa maculata*) are the least expensive (US$ 1.1 / kg). According to another fisher interviewed there is also a difference in the price offered by the different collectors. The large-scale traders who send their refrigerated lorries from the main towns (e.g. Antananarivo) state the price they will offer to their local collectors at the start of the year. According to this fisher in 2007 these prices varied from US$ 0.5 / kg (October-November) to a maximum of US$ 1.1 / kg (May-July). In contrast the local traders who transport the fish by bicycle offer a price that is determined by the freshness of the fish. From 0400-0700h they offer US$ 1.3 / kg; after 0700h they offer US$ 1.2 / kg.

This interviewee was questioned further to ask why he thought other fishers do not use the fish collectors who transport their fish by bicycle, as they would appear to offer the highest price throughout the year. He explained that the large-scale collectors give money (equivalent to US$ 60) to particular local fishers who then distribute this money to other fishers facing economic hardship. In return recipients of this financial support are expected to sell their fish to the large-scale traders in the future.

Impact of closed fishing season: While there was general support for the goal of the two-month no-fishing period (Durbin et al. 2003), interviewees expressed concern over its immediate impact on their lives. One fisher said that while he recognized the value of the closed season in terms of recovering fish stocks over the longer term, in the meantime he had to borrow money from others in the village in order to feed his family during the closed season. Another fisher stated that he was, *"...obliged to go fishing* [during the closed season] *but without the authorities knowing"*. A third stated that, *"...during the closed fishing season there are people who don't respect the law because they have to eat"*.

One young couple was discouraged from entering fishing as their sole profession *"because during the closed season you cannot earn anything. So it is necessary to be a rice cultivator and a fisher at the same time"*. The wife of one fisher interviewed added that if the goal of external organizations (e.g. conservation organizations, government institutions) is to develop a sustainable fishing industry they need to help the fishers develop alternative livelihood options during the closed season.

Desire to shift from fishing to rice cultivation: The mean annual income for fishers who responded to the questionnaire was 4,977,818 ± 997,837 Ariary (n=88) (US$ 2,595 ± 520) compared to approximately 2,361,904 Ariary ± 1,055,030 (n=73) (US$ 1,231 ± 550) for rice cultivators in 2007. However, of those fishers who expressed an opinion about future career moves during the interviews (n= 7) the majority (n= 4) wanted to leave fishing to become rice cultivators. One interviewee stated that while fishing had the potential to generate more income than rice cultivation, income from rice cultivation was more reliable.

The ability of either fishers or rice cultivators to purchase new land now appears to be limited. Landowners do not tend to sell their land once they have acquired it, thereby reducing availability for purchase. Of the 59 land owners questioned, who had owned land for at least the preceding three years (2005-2007), only 11 (18 %) of them had either bought additional land or sold some of their existing land since its original acquisition. Of these 11 landowners only one sold land since he first acquired it in 2005.

VARIABILITY IN RICE HARVESTS AND PRICES. Rice cultivators who had maintained the same area of land from 2004 onwards (n=54) have experienced large fluctuations in their annual rice harvests (Figure 2). The minimum in 2005 coincided with a reported flood that destroyed harvests and forced villagers out of Anororo. There is a concern that the land developed for rice cultivation around Anororo is declining in productivity. One cultivator explained that earlier on in his career as a rice cultivator the fields were fertile and required little in the way of additional fertilizer to produce healthy crops.

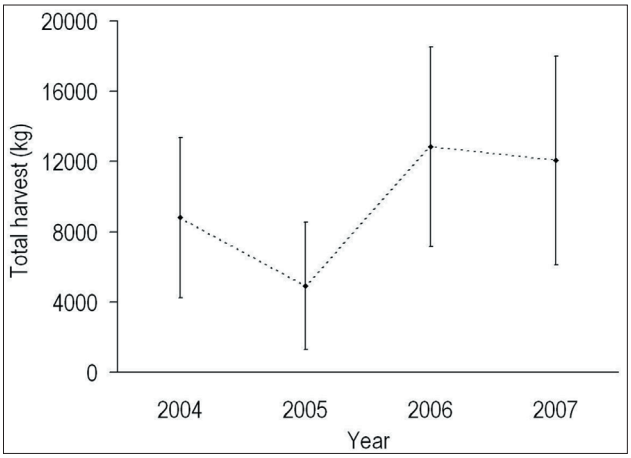

FIGURE 2. Change in reported annual rice harvests (land area staying constant), 2004-2007 (n=54). Error bars refer to 99 % confidence limits.

However, now he felt that artificial fertilizers were required to produce a healthy rice harvest. According to him the cost of purchasing these fertilizers was prohibitive in comparison to the income achieved from rice sales. He quoted a cost of 600 Ariary/kg [US$ 0.35 / kg] for the fertilizer, while rice could be sold for between 300-400 Ariary/kg [US$ 0.18-0.2 / kg]. He implied that this was particularly an issue for small-scale rice cultivators who could not buy fertilizers in bulk or hold onto the rice harvests until higher rice prices could be achieved.

Rice cultivators highlighted the increase in sedimentation in the rice fields due to poor irrigation as a current concern, one cultivator stating that *"…there is a problem with the irrigation and also the sediment that collects in the rice fields that impoverishes the soil"*. Human population increase was identified as a causative factor, another cultivator saying that, *"…it's because there are lots of people – many people to feed in the family so the harvest is insufficient"*. The tradition of dividing up land between siblings may be contributing to this pressure. In one example from Anororo an interviewee explained how his parents had owned 27 hectares of land; as a consequence of divisions between siblings this interviewee's children will inherit one hectare each.

The impact of flooding on rice harvests during the rainy season is of particular relevance to the low-lying traditionally managed fields lying outside the irrigated zone. One cultivator stated that, "*…a part of* [my] *rice fields are low-lying and they don't produce* [anything]- *they are flooded all the time"*. However, there is now a concern that the more elevated, irrigated rice fields are under threat due to a lack of maintenance of the irrigation channels. According to one couple interviewed they intend, *"… starting a second activity, producing textiles, because the production of rice is insufficient as a result of the flooding during the rainy season…the drainage channels and irrigation canals are not dredged …"*.

As with fishers, rice cultivators also have to contend with variations in the price for any rice sales made to local rice traders during the year. The mean price offered by ten local rice traders interviewed in Anororo varied from a low of 320 Ariary / kg [US$ 0.17 / kg] during the rice harvest in June 2006 to a maximum of 660 Ariary / kg [US$ 0.34 / kg] in December 2006.

One rice cultivator expressed a view that the large-scale rice collectors from outside of Anororo are suppressing rice prices. According to him the regional micro-finance facility expects farmers to repay loans by the end of August. Again according to this one interviewee the large-scale rice collectors from the major cities know of this deadline and so keep the price they are willing to pay for rice from the cultivators low until after this date. He stated that by doing so rice collectors were able to force rice cultivators in the town to sell their rice to them at a low price.

HOPE FOR THE FUTURE. Respondents to the questionnaire were asked to give their hopes and aspirations for the future. Hopes were defined as the changes they would like to see happening in an ideal world that would be of greatest importance to them as individual villagers. While many respondents to this question (n=43) expressed a desire for the wetland to be protected, the majority (n=57) were concerned with obtaining external investment in fishing and rice cultivation (Figure 3). A desire for fish and rice prices to be better regulated was also commonly cited.

DISCUSSION

The primary concern of fishers and rice cultivators living in Anororo is how to contend with variability in their respective harvests and the financial returns they can expect from them. While they voice a hope for better environmental protection in the future, their principle desire is for economic support for their livelihoods. Linked to this is a hope for better regulation of both fish and rice prices so they can better predict the incomes they will receive.

Variability in fish catches is a fact of life for fishers globally (Acheson 1981, McGoodwin 1990: 7-20). It has been suggested that around Alaotra fish catches are highest when the rains come and the water level of the lake rises between December and February (Blanc-Pamard 1987). According to fishers interviewed in the current study fish catches can vary on a daily basis depending on the location; the equipment used; the position of the moon; the temperature; as well as water height.

Regardless of how much fish is caught, small-scale fishers around the world also have to contend with variability in the income they can receive (McGoodwin 1990: 7-20). In Anororo fish prices vary depending on the species caught, who the fish is sold to and when the fish is sold. Although higher prices can be obtained from the small-scale 'bicycle' fish traders the large-scale collectors from Antananarivo and elsewhere have the financial means to secure fisher's loyalty. This sort of relationship between fisher and fish trader is not uncommon in small-scale fishing societies (Acheson 1981). Due to the unpredictability of fishing as a livelihood fishers may find it difficult to access capital through the normal banking system. Traders can take advantage of this by providing fishers with a necessary financial cushion during hard times in return for long-term access to their fish catches at competitive rates.

The establishment of a two-month closed fishing season in Alaotra would appear to be compromising fisher's ability to make a living, at least over the short-term. Diversity of livelihood can provide resilience to the external impacts of catastrophes (such as fish population crashes) and regulations, such as those imposed in Alaotra. Whether or not any reduction in income from fishing is being compensated for by other work is an area requiring further research. Livelihood diversification is a common feature of the rural economy across Africa (Barrett et al. 2001). In particular it would be important to investigate the role of women's earnings on household income. For example women in lakeside communities around Alaotra are involved in the production and sale of baskets, mats and hats woven from

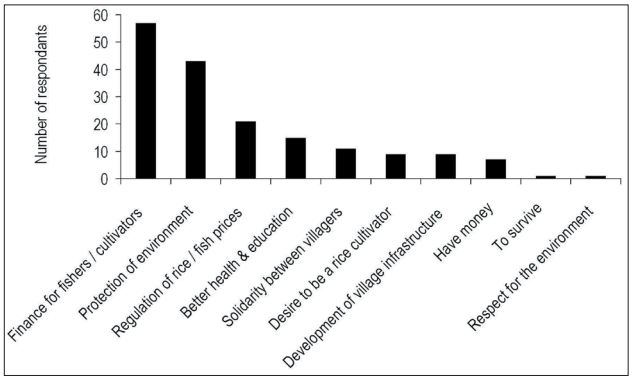

FIGURE 3. Hopes for the future expressed by questionnaire respondents (n=116).

reeds growing in the wetland (Jarosz 1994). Local fish traders and consumers may also be adversely affected by the closure; as such controls can cause disruptions to markets as supply is discontinued (McGoodwin 1990: 7-20).

Fishers in Anororo reported mean annual earnings of US$ 2,780 in 2007, which is more than double that reported for rice cultivators (US$ 1,335) and over three times the mean GDP per capita for Madagascar of US$ 856 in 2006 (UNDP 2006). A study conducted by Andrianandrasana (2005) estimated mean salaries around Lake Alaotra to be between US$ 1,000-1,500 per annum, highlighting the relatively high incomes that can be gained from fishing in Anororo at present. Despite this fishers report a desire to move into rice cultivation. This shift may in part be due to a desire to achieve a degree of food security (Smith et al. 2005). In a study conducted by Barrett (1994) up to 85% of the rice harvested in Madagascar was retained for subsistence. Therefore, although fishers on average may be able to earn higher annual incomes than rice cultivators they are unable to secure a supply of rice for family consumption, unlike rice cultivators.

Even if fishers have the capital to purchase land there appears to be limited opportunity to do so. Land scarcity is a major problem facing rice farmers in this area (Randrianarisoa and Minten 2001). Immigration pressure may have played a role in this increased competition for the same area of land. Since the establishment of irrigated rice fields in the 1960s there has been unprecedented immigration into the Alaotra region (Garin et al. 1994). The tradition of dividing land between siblings has also had an impact. A study conducted on land ownership around Lake Alaotra concluded that over 40% had been inherited from other family members (Jacoby and Minten 2007). Elsewhere in Madagascar this form of land division between siblings is putting additional pressure onto the land to produce (Kistler and Spack 2003). Land can be rented in return for an amount of money or a proportion of the harvest (Blanc-Pamard 1987). However, rice cultivation around Anororo does not come without its own risks and vulnerabilities.

Soil degradation is a significant problem for rice cultivators in this area (Randrianarisoa and Minten 2001). Cultivators interviewed in the present study perceived a reduction in soil fertility and the impact this has on small-scale farmers who may be unable to purchase the chemical fertilisers necessary to maintain soil fertility. Sedimentation and flooding of the rice fields is further reducing rice harvests, according to villagers interviewed. Sedimentation in the lake has been accentuated due to deforestation in the hills surrounding the wetland (Andrianandrasana et al. 2005), which in turn is reducing the productivity of the land (Bakoariniaina et al. 2006). Serious flooding of standing rice fields in the eastern Alaotra region was reported for the start of March 2005 (FAO 2005). Increased siltation of the drainage channels is increasing the susceptibility of the rice-growing land to flooding (McHugh et al. 2003). Mean rice harvests in 2005 reported by rice cultivators during the present study were less than half that given for 2006 and 2007, suggesting a potentially devastating impact on household security for those farmers normally able to meet subsistence needs only.

Even when farmers are able to produce a surplus of rice for sale they may well be forced to sell any excess immediately after the harvest in order to repay personal debts incurred leading up to the harvest. Interviewees in the current study mentioned the need to repay debts incurred immediately following the harvest. One interviewee claimed that the large-scale rice collectors were forcing indebted farmers to sell their rice at a low price as the farmers were obliged to repay their micro-finance loans within a fixed period. Local elites, backed by State officials have reportedly continued to dictate rice prices around Alaotra, thereby preventing free-market forces to operate (Barrett 1994). By selling immediately after the harvest these small-scale producers are unable to take advantage of price increases that occur later in the year as availability of rice locally declines.

For rice consumers these price changes will also have an impact. The majority of rice farmers in Madagascar are in fact net consumers of rice (Barrett 1994). For those farmers in Anororo unable to meet their subsistence needs and those individuals who grow no rice at all, these price changes are likely to put extra strain on an already fluctuating income-base.

Not surprisingly, the main hope for the future expressed by fishers and rice cultivators alike was for external investment into their professions. The results of a development workshop run by the regional government in Anororo to determine the main concerns of people within the village showed that their principal desire was for improvements in production (Plan Communal de Développement 2004). In this workshop preservation of the natural resource base was ranked eighth, bottom in terms of their priorities for change. While it is unknown to what extent and in what format people within the village contributed to this workshop the low concern placed on the environment in comparison to improving production suggests that the priority for local people is for immediate livelihood improvements and not long-term environmental protection.

CONCLUSION

There is little doubt that the loss of Lake Alaotra and its surrounding wetland area will not only threaten local biodiversity but will further reduce livelihood security for lakeside communities. However, conservation measures designed to achieve long-term goals must reflect the immediate concerns of local communities. Further research should be conducted in other lakeside communities to determine the extent to which they express the same views and concerns as those expressed by people in Anororo. Additional studies are required to establish the extent to which alternative livelihoods (e.g. producing reed-based textiles for sale) do currently or could in the future provide resilience for fishers and rice cultivators during hard times. In the case of Anororo, one answer may be for non-government (e.g. conservation charities) or government organizations to provide financial resources to support the development of fishing and rice cultivation in order to secure livelihoods. Ultimately, if future conservation-oriented goals are to be achieved they must in the meantime provide additional resilience for the lives and livelihoods of the people of the marsh.

ACKNOWLEDGEMENTS

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Establishment of a community managed marine reserve in the Bay of Ranobe, southwest Madagascar

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ABSTRACT

The Bay of Ranobe, in southwest Madagascar, once noted for its high biodiversity and fish abundance, is under increasing pressure from overfishing, pollution, sedimentation and tourism. The declining health of the coral reef is reflected in fishery productivity and survey data on biological diversity.

Sustainable conservation requires the engagement of all interested parties and the integration of their needs into resource management. The British NGO ReefDoctor has adopted this approach in establishing the first community-protected site in the Bay of Ranobe, the Massif des Roses. This is a large coral patch with a high percentage of live coral cover (38%) and important fish diversity compared to other sites surveyed in the lagoon. Since 25 May 2007 it has been legally recognised as a community managed marine reserve under temporary protection where fishing is banned. Tourists must now pay an entry fee to visit the site, with the proceeds contributing to the funding of community projects. In conjunction with the protection of this site, ReefDoctor has worked with local people, regional and local government, tour operators and hotels, and conservation organisations to set up 'FIMIHARA', an association representative of local people responsible for the management of this site and the development of sustainable conservation initiatives in the Bay of Ranobe.

This paper explains the approach taken by ReefDoctor, by setting up and working with FIMIHARA, to protect the Massif des Roses site and develop other conservation initiatives and community projects in the Bay of Ranobe.

RÉSUMÉ

La baie de Ranobe, au sud-ouest de Madagascar, autrefois remarquable pour sa biodiversité et l'abondance de la pêche, est de plus en plus menacée par la surpêche, la sédimentation, la pollution et le tourisme. Le déclin de l'état de santé du récif corallien se reflète dans la diminution de la productivité des pêcheries et dans les suivis de la biodiversité marine. La situation est à présent critique car les ressources marines associées au récif assurent la subsistance des populations côtières vivant le long de la baie.

Nous considérons ici qu'une protection pérenne nécessite un engagement concret de toutes les parties prenantes - en particulier des communautés locales - et que leurs besoins soient intégrés dans la gestion des ressources. L'ONG ReefDoctor a mis en œuvre cette approche lors de la création de la première réserve marine dans la baie de Ranobe gérée par la communauté locale, le Massif des Roses. Cette réserve est constituée d'un grand massif de corail largement couvert de coraux et abritant une importante diversité de poissons par rapport au reste du lagon. Depuis le 25 mai 2007, ce site est légalement reconnu comme réserve marine communautaire avec un statut de protection temporaire ; la pêche et les pratiques destructrices associées au tourisme y sont interdites. De plus, les touristes doivent désormais payer un droit d'entrée pour visiter le site, qui contribue au financement de projets communautaires. En parallèle avec la protection du site, ReefDoctor a travaillé avec les communautés locales, les responsables nationaux et régionaux du gouvernement, les opérateurs touristiques et diverses organisations de protection de la nature pour créer l'association FIMIHARA, représentative de la population locale. Cette association, qui a un statut légal depuis le 11 avril 2007, a pour but d'améliorer la qualité de vie de ceux qui vivent le long de la baie de Ranobe et de mettre en œuvre des projets de conservation des ressources marines et terrestres dans la région de la baie de Ranobe.

La création de la réserve marine communautaire du Massif des Roses a rapidement connu le succès qui s'est traduit par la vente de plus d'un millier de tickets, mais l'association FIMIHARA doit encore faire face à de nombreux défis. L'objectif principal de l'association à long terme est de développer son indépendance par rapport à l'ONG ReefDoctor et sa capacité à gérer indépendamment les ressources marines de la baie de Ranobe dont les communautés locales dépendent pour leur survie.

KEYWORDS: Conservation, reef, coral, sustainable development.
MOTS CLEF : conservation, récif, corail, développement durable.

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INTRODUCTION

The Bay of Ranobe is situated in the region of Toliara, in south-west Madagascar. A 32 km long reef encloses it; the lagoon is eight kilometers at its widest point and contains patch reefs, seagrass beds and an estuarine mangrove to the north and a fragmented curtain mangrove in the south. There are two rivers on each side of the Bay, the Fiherenana to the south and Manombo to the north. The Bay is situated in one of the poorest regions of Madagascar, which is one of the poorest countries in the world (World Bank 2007), and faces increasing anthropogenic caused pressures. In addition, the local population heavily depends on the natural resources provided by these reefs for their livelihoods (Davies et al. In press).

The Massif des Roses is a patch reef within the Bay of Ranobe (Figure 1). The reef is covering an area of approximately 100 m x 160 m with a depth between two and seven metres. The name of the site comes from the form of foliose corals, which are widespread at the site (in particular *Montipora aequituberculata*). Since 25 May 2007, the Massif des Roses has been recognised as a community managed reserve under a temporary protection status by the *Direction Régionale du Développement Rural* (*Ministère de l'Agriculture, de l'Elevage et de la Pêche*). The protected site also includes seagrass beds and sand surrounding the coral patch. Seagrass constitutes a vital component of coastal ecosystems due to its primary productivity and function as nursery and shelter for fish and large invertebrates (Edgar et al. 2001). These marine habitats provide a natural buffer zone around the corals and make the Massif des Roses an ecologically diverse site.

The Massif des Roses is protected from heavy seas by the barrier reef (Figure 1). The site is situated about two kilometers from the village of Mangily and is therefore easily accessible by pirogues (out rigger canoes) or powerboats; its shallow depth makes it suitable for both snorkelling and diving. However, the Massif des Roses, like the rest of the Bay of Ranobe faces a variety of anthropogenic pressures.

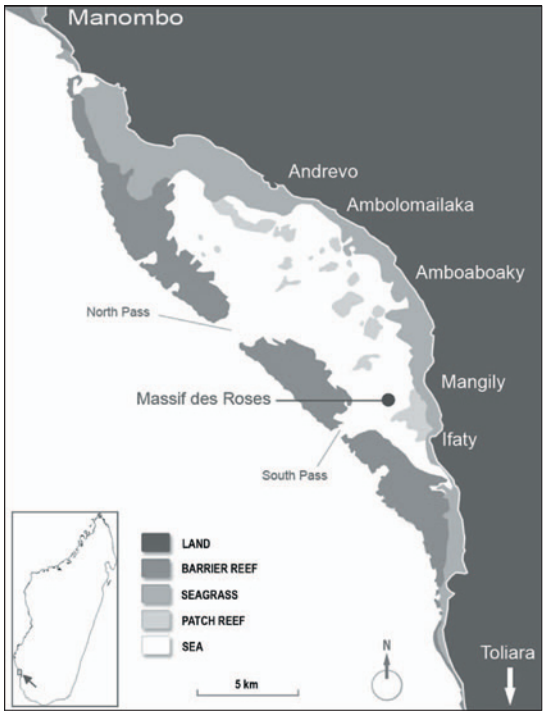

FIGURE 1. The Bay of Ranobe (E43° 30', S23° 00', E43° 38', S23° 18') is protected by a 32 km long reef. This reef is part of the fourth largest coral reef system in the world that extends from Morombe in the north, to Toliara in the south.

TOURISM PRESSURES: The tourism industry provides a major source of income for the Toliara region, and depends to a large extent on a healthy reef, which should provide an economic incentive to protect it. However, as in many places, tourism in the Toliara region is both an asset and a threat. Some of the pressures directly or indirectly caused by tourism include: Destructive anchorage due to the lack of appropriate mooring lines, physical contact with the reef, demand from the hotels for seafood, pollution from hotels due to the lack of sewage facilities, and the curio trade involving the collection and sale to tourists of marine organisms such as shells and starfish.

FISHERIES PRESSURES: The villages along the Bay are inhabited predominantly by Vezo fishermen, who depend almost exclusively on marine resources for food and income. Nearly 50 % of all Malagasy sea fishermen operate in the Toliara region (Laroche and Ramananarivo 1995), and as early as 1988, Vasseur et al. reported a decrease in the abundance and size of fish and increased damage to the reef flat. Overfishing and destructive fishing methods are some major causes of coral reef degradation and are often associated with poverty and coastal crowding (McManus 1997). The population along the coast is growing at a fast rate as is generally the case in Madagascar (3 % nationally on average) (World Bank 2007), which contributes to increased fishing pressure on the reef. In addition, migrants from inland areas drawn to the site by its fishing reputation have often adopted, due to their lack of fishing tradition, destructive fishing methods, such as beach seine fishing with small mesh nets (Gabrié et al. 2000). Overfishing not only directly reduces fish numbers, but also impacts coral reef health by removing herbivorous fish species, resulting in overgrowth of algae, which can result in a phase shift of the ecosystem from coral to algae (McManus et al. 2000).

SEDIMENTATION AND POLLUTION PRESSURES: Coral reefs are also affected by activities in their terrestrial drainage basins. Urbanisation and the intensification of land use can increase the run-off of sediment, nutrients and pollutants which may adversely affect coral reefs and their associated organisms (Grigg and Dollar 1990). It is also known that anthropogenic nutrient enrichment has a greater effect on coral reefs closer to shore and within lagoons (Szmant 2002), like the Bay of Ranobe. The fact that there are no sewage treatment facilities neither in the city of Toliara, nor in the growing villages along the coast, adds to this problem.

Deforestation is considered to be a significant threat to the Bay of Ranobe reef system. The destruction of forests for agriculture, fuel and construction leaves the exposed soil vulnerable to large-scale erosion. The Fiherenana and Manombo rivers flanking each side of the Bay carry large quantities of sediments into the lagoon. High sediment concentrations are a serious threat to corals as they reduce light penetration, thereby affecting photosynthesis of symbiotic algae zooxanthellae. As a consequence, fleshy macro algae outcompete coral in the presence of excess nutrient-rich organic terrestrial sediment (Umar et al. 1998). Healthy mangroves moderate the sediment problem, acting as a natural filter trapping sediment and nutrients (Bouillon et al. 2004). However, much of the mangrove habitat has been lost through deforestation for use as firewood, like in many other places in Madagascar (Dave 2006).

As a result of anthropogenic activities, the reefs may show reduced resilience and be more easily affected and possibly degraded by disturbances such as storms, temperature increases and changes in sea level (Moberg and Folke 1999). As early as the 1960s scientists studying the coral reefs of the region of Toliara (see Thomassin 1971 for a review) observed an increase in the threats to the ecosystem, and noted particular concern about damaging human pressures (Vasseur 1988). In recent years both villagers and tourist operators (e.g. dive clubs and hotels) have become increasingly aware of pressures and their impact on the reef, especially within the lagoon, and are beginning to understand the need to protect the remaining healthy sites, such as the Massif des Roses.

The Massif des Roses has had informal protection for nearly a decade after tourist operators persuaded the mayors of Ifaty and Mangily (Figure 1) that it was in their mutual interest to protect it from fishing. However, the informal protection of the site had only limited success; fishermen saw little benefit in not fishing one of the lagoon's best sites, and tourist operators such as pirogue owners continued to damage the coral by dropping anchor, unaware of the agreement or the impact they were having. Even when transgression was observed and reported to the village mayors, culprits received no more than a warning. As a result, friction and mistrust grew between tourist operators and fishing community, which further deteriorated their relationship (Mayor of Ifaty, pers. com.).

Finally, the establishment of the Massif des Roses community protected site is in line with the commitment of the Malagasy Government to expand the coverage of protected areas in the country as set out in the National Environmental Action Plan. This programme aims to prioritise marine and coastal ecosystem management and more than triple the nation's coastal and marine protected areas within a period of five years (Gouvernement de Madagascar 2007).

The objective of this article is to describe the approach taken by ReefDoctor to legally protect the Massif des Roses marine reserve. We explain the establishment of the local association FIMIHARA and its role in setting up and managing the site and the development of other conservation and community initiatives in the Bay of Ranobe. We also highlight the challenges faced in putting this approach into practice to inform the adoption of similar approaches elsewhere in Madagascar and perhaps beyond.

IMPLEMENTING THE MARINE RESERVE MASSIF DES ROSES

The NGO ReefDoctor has been working in the Bay of Ranobe since 2002, carrying out research, conservation and education programmes. In particular, it has carried out a number of socio-economic projects including raising local environmental awareness, school restoration and marine education, alternative livelihoods initiatives for villagers such as marketing honey and toy pirogues, and the promotion of solar oven use to reduce deforestation. These community projects helped the NGO win the support and trust of local people and provided examples of the type of work that could later be funded through income from the Massif des Roses protected site. In addition, ReefDoctor conducted a preliminary socio-economic survey of the traditional fishery of the Bay focusing on the villages of Ifaty, Mangily and Beravy, the results of which are discussed in detail in Davies et al. (In press). The main finding of this study was that the fishery was heavily exploited with a predominance of small fish in catches, especially when beach seines were used. This reinforced the need for protection of the bay's resources, ideally with strong community involvement.

In October 2006, ReefDoctor organised a first meeting with fishermen from Mangily and Ifaty to discuss the protection of the Massif des Roses. The fishermen were enthusiastic and agreed to form an association with elected representatives to work with ReefDoctor. The association was called 'FI.MI.HA.RA' (*FIkambanana MIaro sy HAnasoa ny RAnomasina* – Association to Protect and Enhance the Marine Environment).

The association FIMIHARA was legally recognised on 11 April 2007 and a *dina* (local law) was adopted for the protection of the site. In contrast with the previous initiatives in the Bay of Ranobe, which were imposed upon the locals, the ReefDoctor initiative was adopted by the local community itself and incorporated into their local legal system. The legalization of the *dina* is a long process, which is still being carried out. *Dina* have a strong authority at the community level and have already been applied in Madagascar to protect marine areas (Rakotoson and Tanner 2006, Harris 2007). ReefDoctor drew in particular on the example of Nosy Ve island south of Toliara, where a community association (FIMIMANO) was created in 1998 to resolve conflict over the island's natural resources. A *dina* was adopted to establish regulations governing a community managed marine reserve (Rakotoson and Tanner 2006). This association is made of representatives from all the villages in the area that depend on Nosy Ve for its resources. On the advice of the Toliara branch of SAGE (*Service d'Appui à la Gestion de l'Environnement*), and based on their experience with FIMIMANO, the representation of the FIMIHARA association was subsequently extended to all villages of the Bay of Ranobe. The structuring of the association and the necessity to include neighbouring villages were presented at a public meeting of local and regional stakeholders organised by ReefDoctor in November 2006. More than a hundred people attended, representing all key stakeholder groups. However, only two representatives of the tourism industry were present, reflecting the limited success at this stage in engaging them in the project.

The FIMIHARA bureau (or committee) consists of a president, two vice presidents, a treasurer, two secretaries, two accountants, 16 advisers and 20 active members (as of December 2008). The active members elect all committee members; active members pay an annual membership fee of 2,000 Ariary (€ 0.75) and committee member pay 4,000 Ariary (€ 1.50). FIMIHARA members meet every two months to discuss their activities. The association has the following stated objectives:

- Provide a voice for all stakeholders who have an interest in the future of the bay.
- Improve the quality of life of those who live and work along the Bay of Ranobe.
- Work to conserve marine and terrestrial natural resources for future generations.
- Improve knowledge and understanding of the natural environment.
- Provide guidance in managing the community-run marine reserve Massif des Roses.

Table 1 outlines the main role of each stakeholder group and their specific involvement in the FIMIHARA association and the protection of the Massif des Roses.

The association is responsible for overseeing the site, including the employment of a site guardian and collecting revenue from ticket sales and fines; funds generated are used for community projects as identified by FIMIHARA. In support of FIMIHARA, ReefDoctor provides finance, advice, and administrative support such as recording meetings and setting up a bank account.

The association FIMIHARA has the authority to manage the newly created marine reserve, including its financial management. The Massif des Roses and surrounding area covering a total of 1.6 ha (100 m x 160 m) has been recognised as a community managed reserve under temporary protection since 25 May 2007 by the *Direction Régionale du Développement Rural* (*Ministère de l'Agriculture, de l'Élevage et de la Pêche)*, which entails that:

- Fishing is banned within the protected site marked with buoys. Infractions are punishable by fines enforced and collected by FIMIHARA via an on site guardian.
- Dropping anchor is forbidden throughout the protected site; visiting boats must moor to buoys already in place for this purpose within the site, at the edge of the coral. Infractions are punishable by fines.
- The theft of materials from the site such as marking and mooring buoys is punishable by fines.

TABLE 1. Outline of the involvement of each stakeholders in the development of the FIMIHARA association and the Massif des Roses protection.

STAKEHOLDER GROUP	INVOLVEMENT IN FIMIHARA
Local People	
Fishermen and other inhabitants of the bay	Representation on FIMIHARA committee
	Empowered to manage their own marine resources and encouraged to adhere to the laws to protect the Massif des Roses
	Representative (village mayors) commented on draft laws (dina).
Research and Conservation Organisations	
ReefDoctor NGO	Research, education and conservation initiatives in the Bay of Ranobe
	Main actor in the establishment of FIMIHARA and the protection of the site
	Main adviser to FIMIHARA
Service d'Appui Gestion de l'Environnement (SAGE)	Prepared EP3 (Environmental Program 3) as part of the UN Environmental Action Plan for Madagascar
	Advised on laws (dina) and set up of FIMIHARA based on experience of similar association FIMINANO at Anakao.
	Advisory members of FIMIHARA committee
Institut Halieutique et des Sciences Marines (IHSM), University of Toliara	Research and education on the Bay of Ranobe
Private Sector (Tourism)	
Hoteliers and dive centres (represented by the association of hoteliers and the Office Régional du Tourisme de Tuléar, ORTU)	Sell Massif des Roses entry tickets to tourists
	Promotion of protection of Massif des Roses to tourists e.g. by display of environmental information material
	Comment by a representative on drafts of laws (dina)
	Representation on FIMIHARA committee
Pirogue owners	Promote the site to tourists
	Site visits for tourists
	Members of FIMIHARA association
Tourists	Pay site visit entry fee to FIMIHARA
	Awareness of site and broader marine conservation issues through visits to site and FIMIHARA environmental information material.
Regional and Local Government	
Communes (Belalanda and Manombo): Mayors / Deputy Mayors	Signed off local laws to establish FIMIHARA and protect Massif des Roses
	Members of FIMIHARA association
Fokontany / Quartier (Administrative units of one or more villages)	Consulted on draft laws
	Signed off local laws to establish FIMIHARA
	Represent local people on FIMIHARA committee
	Members of FIMIHARA committee
Region (Toliara): Direction Régionale du Développement Rural (DRDR) Ministère l'Agriculture, de l'Elevage et de la Pêche	Consulted on draft laws
	Signed off local laws (dina) to establish FIMIHARA and protect Massif des Roses
	Members of FIMIHARA association
Chief of district and chief of Police, Toliara Ministère des Eaux et Forêts	Signed off local laws to establish FIMIHARA
	Officially legalised the status of the organisation

- Tourists who visit the site must pay an entry fee of 2,000 Ariary (€ 0.75)
- A guardian is on site daily to collect tickets and ensure compliance with the law.
- Funds generated from ticket sales and fines are used for community projects as identified by FIMIHARA for the villages of the Bay of Ranobe.

To raise awareness of FIMIHARA's role and authority and build support for the project considerable effort was made to engage local stakeholders. Various means were employed including canvassing Regional Government representatives, organising meetings in all 13 villages along the Bay of Ranobe, creating multilingual publicity material, and visiting all tourist industry representatives including hotels, dive clubs and the regional tourism office, ORTU (*Office Régional du Tourisme de Tuléar*).

DISCUSSION

Experience has shown that traditional top-down approaches to protected areas are often not effective in achieving conservation objectives and are not sustainable in the long-term; they alienate local resource users and are often perceived as a drain on the resources by the local populations (Brown 2000). Furthermore, protected areas have often negatively affected many indigenous people in Africa (Newmark and Hough 2000). Integrated conservation and development projects now aim at equally focusing on biological conservation and human development (Alpert 1996) and are seen as a means to develop supportive relationships with the communities (Newmark and Hough 2000) by involving them in the conservation project. This concept has been successful at building capacity for conservation amongst local communities, although a period of about a decade was often necessary to observe positive results (Baral et al. 2007).

A failure to engage all interested parties in decision-making can be attributed to the limited success of initial attempts to protect the Massif des Roses. Here the active stakeholder participation, particularly local people, through the association FIMIHARA, rendered it a community-managed project, which is key to its sustainability.

More and more community-based approaches are being implemented in Madagascar (Rakotoson and Tanner 2006, Harris 2007, Watson et al. 2007) and throughout the world (see for example Johannes 2002, Balgos 2005, McClanahan et al. 2006). A review of 25 years of community-based projects for the conservation of coral reefs in the Philippines concluded that community participation and cooperation of all interested parties are essential for sustainable reef management (White and Vogt 2000). A recent review of the management of marine protected areas (MPA) in eastern Africa also suggested that the involvement of local communities who depend on the sites on a daily basis is essential to ensure long-lasting results (Francis et al. 2002). Finally, Beger et al. (2004) reviewed the effectiveness of community-based marine reserves and concluded that for such projects to be successful, the following conditions are necessary: An efficient surveillance of the site, ongoing advice from the organisation that facilitated the establishment of the reserves and the rapid realisation of tangible benefits for local people.

AN INITIAL ASSESSMENT. At the end of 2008, the marine reserve has been in operation for 18 months. During this time more than 1,500 tickets have been sold resulting in a net benefit of over € 1,000, some of which has already been used for community projects. As expected, the site entry fee of less than € 1 has been readily accepted by tourists on the understanding that it contributes to funding community projects and ensures the site protection. Villagers are still in the process of submitting short proposals for community projects to the association. So far the funds generated have been mainly used for the maintenance of the Massif des Roses site, but also allowed to pay for sanitation workers in Ifaty, to make a small contribution to the opening of a local clinic in Ambolimailaka and to the refurbishment of a middle school in Mangily, and to fund a small portion of the costs associated with the opening ceremony of new marine reserves and No Take Zones (see below). Importantly, more than a year after its creation, all key stakeholders continue to be supportive of the project. Notably, dive centres are now working more closely with FIMIHARA and ReefDoctor and have been particularly helpful with the initial set up and maintenance of the site.

The presence of a guardian clearly acts as a strong reinforcement of the *dina* in particular with regard to fishing and anchoring and ensuring entrance fee payment. There has been only one known instance of transgression of the laws. In February 2008, three pirogue fishermen were reportedly caught fishing with nets on the site; a fine was successfully imposed.

CHALLENGES AND LESSONS LEARNED. Although the Massif des Roses marine reserve proved to be a clear success in terms of its popularity with tourists with more than a thousand tickets sold in 18 months, the FIMIHARA association has also faced a number of problems over its first two years of existence. Convincing local people that the intention of FIMIHARA was to provide local benefit proved difficult, but was facilitated by the NGO's Malagasy local staff. It is a continuous challenge to steer the aspirations of some committee members away from a fisheries focus and towards sustainable resources management. ReefDoctor continues to advise FIMIHARA, but with the long-term aim of enabling the association to operate independently. A challenge for FIMIHARA in achieving its objectives is that it lacks full support from some parts of the community it represents; it is regarded by some as benefiting a small closed group of people only rather than the wider community. Concerns have been encouraged by an initial lack of transparency in accounting, and perception of weak leadership.

Because ReefDoctor played such a pivotal role in setting up the association and in providing advice on its management there have been some misunderstandings about roles and responsibilities. There is an ongoing need to reinforce the fact that FIMIHARA is a local association, assisted by the NGO but managed and run by local representatives. In addition, it has been difficult for the association to find capable, trustworthy and motivated staff; there have been instances with previous guardians fishing in the reserve and pocketing entrance fees.

The fact that the association was initially meant to include only the villages of Ifaty and Mangily (Figure 1) has sometimes led to a feeling of disenfranchisement in other villages. In order to counteract this perception of unequal engagement and benefit, it was decided that for the next elections of the FIMIHARA committee, each region of the Bay (southern, central and northern) would present two candidates for president; the

elected president would then be joined by two vice-presidents, each coming from a different area of the bay.

Finally, FIMIHARA still relies heavily on ReefDoctor for its operation. The NGO's budget is currently between 15 and 20 million Ariary (between € 5,600 and € 7,500) a month to cover operational costs. We believe that the replication of such project elsewhere would require similar ongoing financial commitment. The approach is likely to be difficult for local communities without external funding. ReefDoctor aims to continue capacity building over the next few years, including for instance, workshops on simple accounting, profit monitoring and public relations.

LONG-TERM ENGAGEMENT. The long-term goal is to continue to protect the Massif des Roses from further damage and to allow its biodiversity to recover, although it is too early yet to assess ecological improvements due to site protection. However, to measure the impact of marine reserves on the conservation of biological diversity, ReefDoctor has set up a bi-annual biodiversity monitoring programme by means of underwater survey transects to allow the comparison of protected reserves and other sites both within and outside the lagoon. These monitoring results will allow for comparison of current marine ecological state of the Bay with older survey data sets (e.g. Thomassin 1971). As the scope of work of FIMIHARA broadens within the bay, the representation of the stakeholder interests is regularly reviewed on a two months-basis during FIMIHARA meetings. More and more responsibility and political power is handed over to other villages outside Ifaty and Mangily.

The Massif des Roses's earlier informal protection and tourist interest clearly facilitated the establishing of a marine reserve. The establishment of similar reserves in other sites lacking such history may prove more challenging. Also, the long-term sustainable protection of the Massif des Roses is not guaranteed by its protection status alone. Ongoing participative, effective and transparent operational management is important if Massif des Roses is to provide a model for similar projects elsewhere, not least within the Bay of Ranobe.

As part of the long-term plan to protect additional sites within the Bay of Ranobe, on the 1 December 2008, three more locally recognised marine reserves were established at the following locations: Ankarandjelita in the north, Ankarabory which is situated to the northwest of the Massif des Roses and Andabotira in the south. In addition, six temporarily protected octopus fishery areas (No Take Zone, NTZ) have been closed for fishing for six months. A similar initiative was carried out in Andavadoaka (E43º 13'30, S22º 04'22 , southwest Madagascar) with the creation of a network of community-run protected areas set up by the British NGO Blue Ventures; however, insufficient NTZ were closed at the same time, which resulted in over-harvesting on reopening (Harris 2007). In the Bay of Ranobe, we hope that the simultaneous closure of six discrete and widely separated areas will counteract similar problems and improve the sustainability of the octopus fishery.

FUTURE PROJECTS. As well as seeking to work collaboratively with conservation bodies, FIMIHARA and ReefDoctor have received funds from the United Nations Development Programme Small Grants Project for the following projects to be implemented within the Bay of Ranobe: The creation of artificial reefs outside the lagoon using fish aggregation devices, the restoration of mangroves, and a programme of fishing gear exchange whereby destructive equipment such as beach seine nets are exchanged for gill nets of larger mesh size. Future planned FIMIHARA projects include the introduction of restrictions on the use of damaging fishing equipment, setting up an association of pirogue tourist operators, the development of artisanal products such as handicrafts and ecotourism employing marine guides for the Marine Protected Areas.

The sustainable conservation of the Massif the Roses is important for the communities who live in the Bay of Ranobe and depend almost exclusively on its resources for their livelihood (Davies et al. In press). Long-term success to sustainably manage, conserve and possibly restore the Bay of Ranobe in order to build resilience to climate change and other pressures will depend on the development of local governance and capacity building such as strengthening internal governance, developing external communications and encouraging better transparency in accounting. The association therefore remains the basis on which to build further sustainable resource management initiatives such as the new marine reserves and NTZs established in 2008.

CONCLUSION

Our study shows that all stakeholders' interests need to be taken into account for an efficient ecological protection of a site, which requires a careful balancing of all the values and factors involved: Local people and their respective cultures, community politics, fisheries and other livelihoods, ecological needs and tourism. FIMIHARA has played an essential role in the establishment and operation of the Massif de Roses and, more importantly, in empowering and engaging the communities of the Bay of Ranobe. The association will now be crucial to assure long-term local protection of the Massif des Roses and success of subsequent projects. To this end, it is important that FIMIHARA increasingly takes the lead in managing the marine resources of the Bay of Ranobe.

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The lemur diversity of the Fiherenana-Manombo Complex, southwest Madagascar

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ABSTRACT

We conducted the first comprehensive lemur survey of the Fiherenana-Manombo Complex (Atsimo-Andrefana Region), site of PK32-Ranobe, a new protected area within the Madagascar Protected Area System. Our cross-seasonal surveys of three sites revealed the presence of eight lemur species representing seven genera and four families, of which three are diurnal and five are nocturnal species. Six species were only recorded in the riparian and transitional forests of the Fiherenana and Manombo river valleys, while the spiny thicket at Ranobe contains only *Microcebus* (two species), all larger species having been extirpated by hunting in recent years. Two of our records (*Mirza coquereli* and *Cheirogaleus* sp.) represent new locality records or range extensions, but we failed to record one species (*Phaner pallescens*) expected to occur in the area, and question the literature supporting its presence south of the Manombo river. Our findings highlight the importance of the Fiherenana-Manombo Complex for the conservation of lemurs in southwest Madagascar, but also show that PK32-Ranobe fails to protect the full lemur diversity of the Complex. The protected area does not include the riparian forests of the Manombo and Fiherenana rivers, and at least three lemur species are therefore unprotected. We strongly support the proposed extension of the protected area to include these riparian forests as well as other important habitats for locally endemic bird and reptile taxa.

RÉSUMÉ

La zone du Complexe Fiherenana-Manombo (Région d'Atsimo-Andrefana), site de PK32-Ranobe, une nouvelle aire protégée dans le Système des Aires Protégées de Madagascar (SAPM), a fait l'objet d'un premier inventaire de lémuriens. Nos prospections dans trois sites à différentes saisons ont révélé la présence de huit espèces de lémuriens représentés dans sept genres et trois familles, dont trois sont des espèces diurnes et cinq sont des espèces nocturnes. Nous n'avons pas pu identifier l'espèce du genre *Lepilemur* ni celle du genre *Cheirogaleus* à défaut de disposer de spécimens. Six espèces ne se trouvaient que dans les forêts riveraines et les forêts de transition des vallées des fleuves Fiherenana et Manombo. Le fourré épineux de Ranobe n'abrite que des *Microcebus* (deux espèces), toutes les espèces plus grandes ayant déjà été exterminées par la chasse au cours des dernières années. Nos estimations de densité indiquent que la population des *Microcebus* est deux fois plus importante dans le fourré épineux que dans la forêt riveraine (1,078 individus / km² vs. 546 individus / km²). Nous avons estimé la densité d'*Eulemur rufus* à 40 groupes / km² dans la vallée du Fiherenana, mais nos transects ne nous ont pas permis d'obtenir des estimations fiables pour les densités de *Lemur catta* et de *Propithecus verreauxi*. Deux des espèces répertoriées (*Mirza coquereli* et *Cheirogaleus* sp.) représentent de nouvelles observations pour la zone ou des extensions de leurs aires de répartition connues, mais nous n'avons pas pu trouver l'espèce *Phaner pallescens* qui devait être présente dans la zone et nous émettons des doutes portant sur les références publiées rapportant la présence de l'espèce au sud du fleuve Manombo. Nos résultats mettent en exergue l'importance du Complexe Fiherenana-Manombo pour la conservation des lémuriens dans le sud-ouest de Madagascar, mais ils indiquent que l'aire protégée de PK32-Ranobe ne protège pas la diversité complète des lémuriens du Complexe. Les forêts riveraines des fleuves Fiherenana et Manombo ne sont pas incluses dans l'aire protégée de sorte qu'au moins trois espèces de lémuriens ne bénéficient alors d'aucune protection. Compte tenu des objectifs du SAPM et plus particulièrement de l'Objectif 1, à savoir 'Conserver l'ensemble de la biodiversité unique de Madagascar', nous estimons que la nouvelle aire protégée du PK32-Ranobe n'atteint pas ces objectifs et nous appuyons les efforts des promoteurs afin de re-délimiter l'aire protégée pour inclure les forêts riveraines ainsi que d'autres habitats importants pour la conservation des oiseaux et des reptiles localement endémiques.

KEYWORDS: Lemurs, PK32-Ranobe, spiny thicket, SAPM, protected area.
MOTSCLEF : forêts riveraines, Manombo, Fiherenana, SAPM, PK32-Ranobe, lémuriens.

INTRODUCTION

The lemurs are the best known of Madagascar's endemic fauna, and as such play an important role as flagships not only for conservation (Durbin 1999, Thalmann 2006), but for the country itself. The level of scientific research on lemurs reflects their flagship status, but despite this many aspects of lemur distribution

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and taxonomy remain poorly known. This is illustrated by the extraordinary rate of new species description over recent years; while Mittermeier et al. (1994) considered 34 taxa to merit full species status, this number has more than doubled and is still growing (e.g. Thalmann 2006, Craul et al. 2007, Tattersall 2007, Lei et al. 2008, Mittermeier et al. 2008). Three trends have contributed to this growth in species numbers: 1) the discovery and characterisation of new forms, 2) the resurrection of synonyms and 3) the application of new species concepts (Thalmann 2006). The underlying factor is, of course, a huge increase in the level of research effort in lemur taxonomy, distributions and ecology, but despite such effort many areas of the country remain little known or un-surveyed, including many forest areas considered to be national or regional conservation priorities.

The Fiherenana-Manombo Complex, also known as the Southern Mikea / Mikea Sud, Toliara forest and PK32-Ranobe, has long been recognised as a conservation priority area (Domergue 1983, Nicoll and Langrand 1989, Ganzhorn et al. 1997, ZICOMA 1999, Seddon et al. 2000). Forming part of the South Mangoky centre of micro-endemism (Wilmé et al. 2006), the area lies to the north of the regional capital of Toliara (Atsimo Andrefana Region) on Madagascar's southwest coast, stretching between the Fiherenana River to the south and the Manombo River to the north. It is bordered to the west by the Mozambique Channel, and extends to the eastern edge of the Tertiary limestone Mikoboka Plateau (Figure 1). The climate is sub-arid, receiving 100-1,300 mm of rainfall per annum, most of which falls between November and March – the 'rainy season' (Seddon et al. 2000). The site is characterised by its diversity of habitats, influenced by heterogeneous geology (Du Puy and Moat 1996) and north-south and east-west gradients in rainfall (Rakotomalaza and McKnight 2006). The vegetation is broadly classified as 'southwestern dry spiny forest-thicket' (Moat and Smith 2007), and distinct sub-types can be recognised growing on coastal dunes, rufous sands and limestone (Figure 1). There is also a transitional forest between the southwestern dry spiny forest-thicket and the western dry forest that lies to the east of Ranobe (P. J. Rakotomalaza, pers. com.) In addition, riparian forests occur in the Fiherenana and Manombo river valleys, and wetland complexes exist at Ranobe (freshwater) and Belalanda (brackish).

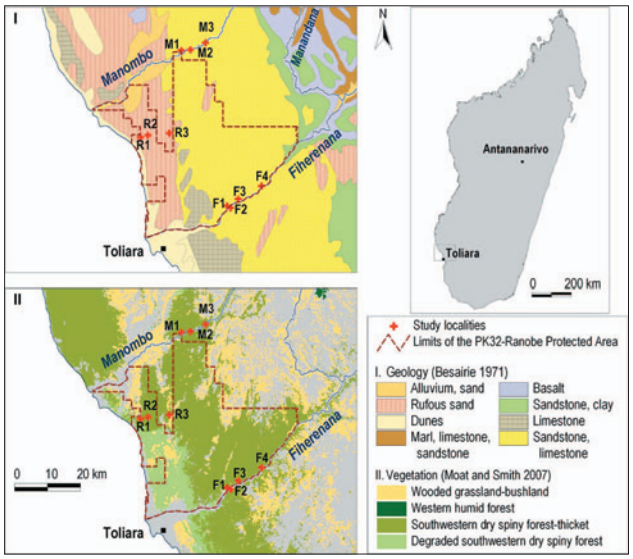

FIGURE 1. Maps of the Fiherenana-Manombo Complex showing vegetation cover and underlying geology, as well as the study locations and the proposed limits of PK32-Ranobe as of February 2009.

Since 2005 the site has been the focus of a WWF-promoted initiative to establish an IUCN Category V protected area within the Système des Aires Protégées de Madagascar (SAPM, Madagascar Protected Area System). A co-management model was proposed for the future Protected Area (PA), and the inter-communal association MITOIMAFI created to regroup the eight rural communes that would be implicated in the proposed PA into a community co-management structure. A *Demande de Protection Temporaire* (request for temporary protection) for a protected area of 287,350 ha was submitted by WWF in 2007, but due to conflicts with three mining concessions or exploration areas, an *Arrêté de Protection Temporaire* (n° 21482-2008 / MEFT / MAEP / MEM / MRFDAT) was not granted until 2 December 2008. This decree granted temporary protected status to an area of 77,851 ha centred on the Mikoboka Plateau, composed almost entirely of spiny thicket on limestone habitat. As of January 2009 WWF are seeking to extend the limits of this protected area to include additional habitats not included within the *Arrêté de Protection Temporaire* (Anitry N. Ratsifandrihamanana, pers. com.).

Here we present the results of the first lemur survey of the Fiherenana-Manombo Complex, carried out as part of the Frontier Madagascar Forest Research Programme between August 2002 and December 2004. Inventories were compiled for birds, reptiles, amphibians, mammals and select invertebrate taxa; for a full report of research results for non-lemur taxa, see Thomas et al. (2005). We conducted lemur surveys throughout the year at three sites within the Ranobe Complex and the riparian forests along the Fiherenana and Manombo rivers. Due to logistical constraints, no lemur surveys were carried out on the Mikoboka Plateau. Details of survey locations and survey dates are presented in Table 1.

METHODS

Lemur observations were carried out through both nocturnal and diurnal searches, and incidentally during inventorying of other taxa. In addition, line transects were used to estimate population densities of certain species. Three diurnal transects of 500 m length each were walked in the early morning and late afternoon for seven days each. Six nocturnal lemur transects were walked at least an hour after sunset for three days each. Distance and sighting angle from the transect line were recorded for each sighting of a lemur group (diurnal species) or individual (nocturnal species). Where lemur groups were used, estimates were made to the geometrical centre of the group. Following 'Webb's Method' (Rabinowitz 1997), the mean distance and mean sighting angle of each species to the transect line was calculated to give the mean perpendicular distance, which was considered as half the transect width. Density was estimated by dividing the number of groups or individuals sighted by the transect area (i.e. the total distance walked multiplied by twice the average perpendicular distance). Density estimates for group-living species were therefore calculated in groups / km², whereas non-gregarious species densities are calculated as individuals / km². Effort was recorded in 'transect kilometres'. Due to the logistical constraints of accessing the river valley habitats, diurnal species were only censused in riparian forests. Population densities of nocturnal species were estimated only

TABLE 1. Details of survey locations.

Study Location	Survey site	Habitat type	Longitude	Latitude	Dates surveyed	Total survey period (days)
Fiherenana River valley	F1	Riparian forest, spiny thicket on limestone	E043° 52′ 14.4″	S23° 14′ 10.0″	11-28 VIII 2002 12 X-10 XII 2002 5 VII-28 VIII 2003	135
	F2	Spiny thicket on limestone	E043º 51′ 36.6″	S23º 13′ 51.0″		
	F3	Riparian forest, transitional forest	E043° 53′ 36.1″	S23° 12′ 44.2″		
	F4	Riparian forest, transitional forest	E043º 57′ 44.8″	S23º 10′ 40.2″		
Ranobe Lake and forests	R1	Freshwater lake and reed beds, transitional forest	E043º 36′ 34.2″	S23º 02′ 24.6″	14 I-28 III 2003 13 IV-4 VI 2003 14 X-8 XII 2003 16 I-4 III 2004 5 VII-29 VIII 2004	292
	R2	Transitional forest, spiny thicket on red sand	E043º 37′ 52.1″	S23º 02′ 05.5″		
	R3	Anthropogenic grassland, spiny thicket on limestone	E043º 41′ 38.2″	S23º 01′ 47.9″		
Manombo River valley	M1	Riparian forest	E043° 44′ 02.4″	S22° 48′ 21.6″	17-31 I 2004 21 II-5 III 2004 5 IV-31 V 2004 7-16 VII 2004 11 X-4 XII 2004	151
	M2	Riparian forest, transitional forest	E043° 45′ 38.7″	S22° 48′ 16.0″		
	M3	Riparian forest, transitional forest, spiny thicket on limestone	E043° 48′ 19.0″	S22° 47′ 10.0″		

at Ranobe, in both spiny thicket and riparian forest surrounding Lake Ranobe. In total we conducted 17.5 km of dry season diurnal transects in the Fiherenana forests and nine kilometres of dry season nocturnal transects at Ranobe. No voucher specimens or DNA samples were taken during our survey, with the result that some taxa are identified only to genus level.

RESULTS

We recorded eight lemur species distributed across seven genera and four families (Table 2). Four of these species are classed as Vulnerable in the IUCN Red List of Threatened Species (IUCN 2008). The Fiherenana (six species) and Manombo (seven species) river valleys harboured greater species diversity than Ranobe (two species), due partly to habitat differences between these sites (but see discussion). Six species were recorded only in riparian and transitional forests, while only two species were recorded in spiny thicket. Two taxa, *Cheirogaleus* sp. and *Lepilemur* sp. could not be identified without capture of an animal, due to the unclear taxonomy or distributions of the species in question.

Table 3 gives density estimates for diurnal species in degraded riparian forest along the Fiherenana River, and for *Microcebus* spp. in both spiny thicket and degraded riparian forest at Ranobe. Note that data on both *Microcebus* species are pooled in this analysis because although species identity could be established in some cases, this did not yield sufficient data for meaningful inter-site comparisons of the *Microcebus* taxa. Along the Fiherenana River, density estimates for *Eulemur rufus* at 40 groups / km² were high compared with the apparent absence of *Propithecus verreauxi*. These results clearly underestimate the very low densities of *P. verreauxi* and *Lemur catta* that were observed in the small pockets of riparian forest along the Fiherenana. Estimates of mouse lemur (*Microcebus* spp.) populations at Ranobe suggest that spiny

TABLE 2. Lemur species recorded from the Fiherenana-Manombo Complex.
Habitat codes: R – Riparian forest, T – Transitional forest between riparian forest and spiny thicket (on valley slopes), S – Spiny thicket;
IUCN Status: DD - Data Deficient, LC - Least Concern, VU - Vulnerable; X: confirmed, ?: unconfirmed record of the species.

Latin name	Common name	Fiherenana	Ranobe	Manombo	Habitat	IUCN Status
Cheirogaleidae						
Cheirogaleus sp.	dwarf lemur	X		X	R, T	DD
Microcebus murinus	Grey mouse lemur	X	X	X	R, T, S	LC
Microcebus griseorufus	Reddish-grey mouse lemur	?	X	?	S, R	LC
Mirza coquereli	Coquerel's giant mouse lemur	X		X	R, T	VU
Indriidae						
Propithecus verreauxi	Verreaux's sifaka	X		X	R, T	VU
Lemuridae						
Eulemur rufus	Red-fronted brown lemur	X		X	R, T	LC
Lemur catta	Ring-tailed lemur	X		X	R, T	VU
Lepilemuridae						
Lepilemur sp.	sportive lemur			X	T	VU

TABLE 3. Lemur population density estimates from the Fiherenana-Manombo Complex.
* = Data deficient for density estimate.

Location	Habitat	Transect		Length (km)	Species density (number of sightings)			
		No	Cycle		*Microcebus* spp.	*Eulemur rufus*	*Propithecus verreauxi*	*Lemur catta*
Fiherenana								
S23° 12′ 37.5″ E043° 53′ 38.5″	Degraded riparian	1	diurnal	7	-	62 (16)	0 (0)	0 (0)
S23° 13′ 18.4″ E043° 53′ 02.6″	Degraded riparian	2	diurnal	3. 5	-	9 (1)	0 (0)	(1)*
S23° 10′ 28.2″ E043° 57′ 42.2″	Degraded riparian	3	diurnal	7	-	50 (12)	0 (0)	(3)*
Riparian forest average density(groups/km²)					-	40	0	0
Ranobe								
S23° 02′ 26.7″ E043° 37′ 07.1″	Spiny thicket	1	nocturnal	1. 5	199 (5)	-	-	-
S23° 02′ 17.8″ E043° 37′ 01.8″	Spiny thicket	2	nocturnal	1. 5	1988 (34)	-	-	-
S23° 02′ 04.9″ E043° 37′ 04.0″	Spiny thicket	3	nocturnal	1. 5	1046 (21)	-	-	-
Spiny forest average density (individuals/km²)					1078	-	-	-
S23° 02′ 35.2″ E043° 36′ 35.3″	Degraded riparian	1	nocturnal	1. 5	160 (23)	-	-	-
S23° 02′ 26.5″ E043° 36′ 32.0″	Degraded riparian	2	nocturnal	1. 5	948 (7)	-	-	-
S23° 02′ 16.1″ E043° 36′ 38.7″	Degraded riparian	3	nocturnal	1. 5	531 (21)	-	-	-
Riparian forest average density (individuals/km²)					546	-	-	-

thicket habitats (1,078 individuals / km²) support mouse lemurs at almost twice the density of riparian forests (546 individuals / km²). We did not calculate the area of suitable habitat at any site, and so are unable to extrapolate from our density estimates to arrive at estimates of population size.

DISCUSSION

Our surveys demonstrate that the lemur diversity of the Fiherenana-Manombo Complex is spatially highly variable, with the number of species present at a survey location ranging from two to eight. This finding has important implications for protected area zoning and management planning. The riparian and transitional forests of the Manombo and Fiherenana river valleys, with seven and six species respectively, not only support a greater diversity of species than the spiny thicket, but are also the only sites where six of the eight species are known to occur. These riparian forests make up a small (but unquantified) proportion of the Fiherenana-Manombo Complex (WWF 2007), which is dominated by spiny thicket on red sand (such as that surveyed at Ranobe) and spiny thicket on limestone (which we did not survey). These forests are therefore disproportionately important for the lemur diversity of the sub-region. Among the species we recorded only at Manombo and/or Fiherenana, some (e.g. *Cheirogaleus* sp., *Mirza coquereli*) may be restricted to gallery forests within the southern part of their range. *Lemur catta*, *Propithecus verreauxi* and *Lepilemur* sp., however, probably range widely across the Mikoboka Plateau that lies between these rivers. Our failure to record these species elsewhere should therefore not be interpreted as implying their absence in other areas of the PA (Goodman et al. 2006). The Manombo and Fiherenana riparian forests probably provide important resources for *L. catta* and, to a lesser extent, *P. verreauxi*, providing refugia and food resources (e.g. *Tamarindus indica* Fabaceae) year-round (see Emmett et al. 2003).

Habitat differences alone, however, do not explain the depauperate lemur fauna of the spiny thicket at Ranobe. A review of the literature, supplemented by villager interviews, indicates that several additional species were present in this area until recent times, and that hunting was the primary cause of their extirpation. Domergue (1983) and Nicoll and Langrand (1989) both record *Lemur catta* and *L. fulvus* (=*Eulemur rufus*) from the Site d'Intérêt Biologique du Nord de Tuléar PK32, an area of forest lying several kilometres to the south and contiguous with the Ranobe forests, indicating that these species were present until recent times. These data are confirmed by local ethnoprimatological knowledge: We conducted semi-structured interviews with three groups of men in Ranobe which confirm that until the early 1990s *Propithecus verreauxi*, *L. catta* and *Lepilemur* sp. were all present and actively hunted in the Ranobe area. Respondents suggested that hunting was responsible for the disappearance of these animals and stated that *Lepilemur* could still be found on the Mikoboka Plateau approximately eight kilometres to the east. Hunting of lemurs still takes place along the Manombo river: Two groups of men interviewed claimed to trap and hunt *E. rufus* and *P. verreauxi* during the dry season, but not in the rainy season because their diet makes their flesh bitter to taste. Hunting is carried out for personal consumption, but excess animals may be sold at the market of Andoharano-Morafeno.

The role played by lemurs in seed dispersal and therefore forest regeneration has been demonstrated in both humid and dry forests for a range of taxa, including: *Microcebus murinus*, *Cheirogaleus medius* and *C. major* (Lahann 2007); *Varecia variegata*, *Eulemur rubriventer* and *E. rufus* (Dew and Wright 1998); *E. collaris* (Bollen et al. 2004a, 2004b), and *E. macaco* (Birkinshaw 2001). The importance of *E. rufus* for seed dispersal in western dry deciduous forests has also been highlighted (Ganzhorn et al. 1999, Spehn and Ganzhorn 2000) and, given the similarities between these habitats and the transitional forests to the east of Ranobe, we believe that the extirpation of *E. rufus* and other species from this habitat may have negative impacts on the viability of the full species assemblage of these forests. Further research is required to test this hypothesis.

Our findings add greatly to our knowledge of lemur distributions in the southwest of Madagascar, and two of our records represent range extensions or new locality records. The distribution maps published in Mittermeier et al. (2006) show the nearest populations of *Eulemur rufus* in the Mikea Forest (approximately 60 km to the north) and Zombitse-Vohibasia (approximately 90 km to the northeast), despite the species having twice been recorded at PK32 in the literature (Domergue 1983, Nicoll and Langrand 1989). The Fiherenana population of *E. rufus* may therefore represent the most southwestern extant population in Madagascar of this species. The maps in Mittermeier et al. (2006) also show the distributions of *Cheirogaleus* spp. failing to reach the Fiherenana river, where we recorded *Cheirogaleus* sp. The *Cheirogaleus* species we recorded in the Fiherenana and Manombo forests was initially identified as *Cheirogaleus medius*, but following the resurrection from synonymy of *C. adipicaudatus* (Groves 2000), and in the absence of voucher specimens, this identification must be revised to *Cheirogaleus* sp.

The second new locality record is of *Mirza coquereli*, which Mittermeier et al. (2006) record as being present along the Onilahy River to the south of PK32 Ranobe, but which was not recorded in the Mikea Forest to the north of the Manombo by Ganzhorn and Randriamanalina (2004). This species is restricted to riparian forests both on the Manombo and Fiherenana rivers and on the Onilahy to the south (Emmett et al. 2003), giving it several discreet populations isolated along westward draining watercourses. Given the number of new species described as a result of recent revisions of the Lepilemuridae and the Cheirogaleid genera *Microcebus*, *Cheirogaleus* and *Phaner*, we speculate that similar research effort within the southern *Mirza* population complex may also reveal additional taxa. A number of biogeographical models or speciation mechanisms have been proposed (see e.g. Goodman and Ganzhorn 2004, Wilmé et al. 2006, Craul et al. 2007) that may support this suggestion.

In addition to the new locality records, we failed to record one species, *Phaner pallescens*, said to occur within the study area by Mittermeier et al. (2006), and question the literature indicating the presence of the species south of the Manombo River. Mittermeier et al. (2006) cite an observation of this species south of the Fiherenana River attributed to Ganzhorn and Randriamanalina (2004), but the only record in the cited publication is, according to the geo-coordinates given, actually north of the Manombo, near the *layon pétrolier* linking Ankililoaka and Tsifota. Although Domergue (1983) hesitantly records *P. furcifer* (the southern population of which is now *P. pallescens*) from PK32, stating that in the brief cacophony following sunset "I think I have distinguished the yelping of *P. furcifer* mixed with the cries of *Coua pyropyga*" [=*C. cristata pyropyga*], we are unaware of any confirmed records south of the Manombo.

We were unable to identify the *Lepilemur* we observed near the Manombo River to species level without capturing a specimen. The known distributions of the genus suggest that all populations north of the Onilahy River belong to *L. ruficaudatus* and *L. hubbardi*, but Seddon et al. (2000) report an observation from an unknown location north of the Fiherenana that they provisionally ascribe to *L. leucopus*. Further research is required to confirm the identity of the *Lepilemur* species present within the PA.

CONSERVATION IMPLICATIONS. Our findings highlight the importance of the Fiherenana-Manombo Complex for conserving the lemur diversity of southwest Madagascar, but also show that the new protected area of PK32-Ranobe fails to conserve important elements of the lemur diversity of the zone. We did not survey the limestone Mikoboka Plateau however, and are unaware of any historical records from this area, and so are only able to speculate on the lemur fauna of this new protected area. The riparian forests of the Fiherenana and Manombo rivers, with six and seven species respectively, showed high lemur diversity but are not included in the protected area, and as a result we believe that at least three of the lemur species we recorded still receive no formal protection within this sub-region. These species are *Eulemur rufus*, *Mirza coquereli* and *Cheirogaleus* sp., which we believe to be restricted to or heavily dependent upon gallery forests within the region. The riparian forests of the Manombo River are particularly important given that they are also the only known sites for *Mungotictis decemlineata lineata*, a subspecies of the Narrow-striped mongoose known only from two specimens (Goodman et al. 2005).

The first objective of the Madagascar Protected Area System is to conserve all of Madagascar's unique biodiversity (ecosystems, species, genetic diversity) (Groupe Vision Durban 2006). We suggest that the new protected area of PK32-Ranobe fails to fulfil this objective and conserve the full biodiversity of the Fiherenana-Manombo Complex, because it does not include all the habitats of the area; spiny thicket formations on red sand and white sand, transitional forests, riparian forests and wetlands are not represented (see Figure 1). The spiny thicket on red sand in particular is considered very important for biodiversity (Domergue 1983, Nicoll and Langrand 1989, ZICOMA 1999, Seddon et al. 2000), and is the only habitat of the Vulnerable *Monias benschi* and *Uratelornis chimaera*, two locally endemic, monotypic bird genera of endemic families (Seddon et al. 2000). A number of locally and regionally endemic reptile taxa also occur in these forests (Raxworthy 1995, Thomas et al. 2005), and *Furcifer belalandaensis*, probably the world's rarest chameleon (C. Raxworthy, pers. com.), is restricted to the northern banks of the Fiherenana. We believe that the successful resolution of spatial conflicts between conservation and mining areas is essential and strongly support the promoter's efforts to apply for the expansion and redelimitation of the protected area to include the full range of habitats occurring within the Fiherenana-Manombo Complex. The creation of such a protected area is essential if the full range of species, ecosystems and genetic diversity of the area is to be conserved in line with SAPM objectives.

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The conservation status of mammals and avifauna in the Montagne des Français massif, Madagascar

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ABSTRACT

The Montagne des Français is a limestone massif in northern Madagascar, which is characterised by a wide range of biotopes including xerophytic karst, gallery forest, dry western forest, grassland and caves. It is situated only 12 km from the regional capital, Antsiranana, and few, if any areas of primary forest remain. In the first comprehensive study to have been carried out at this location we report the presence of 12 mammal species. We also report the presence of 63 bird species. We use data derived from both structured and semi-structured interviews to assess the conservation status of the mammals and birds within the massif. Our study shows that local beliefs are dominated by taboos or *fady* and that these vary within families and communities. Current anthropogenic pressures on biodiversity include zebu grazing, charcoal production, hunting and rice cultivation. The massif was afforded Temporary Protected Area Status in 2006 and our results suggest that this protection should be made permanent. We propose opportunities for further research and sustainable development initiatives that could contribute to the conservation of the biological resources within the massif. Success in conserving this area will only be achieved if the local communities are fully engaged.

RÉSUMÉ

La Montagne des Français est un massif calcaire au nord de Madagascar, caractérisé par une vaste gamme de biotopes, y compris une formation calcaire connue localement sous le nom de 'tsingy' avec une végétation xérophyte, une forêt riveraine, une forêt sèche de l'ouest, des zones herbeuses et des grottes. Elle se trouve à 12 km seulement de la plus grande ville du nord, Antsiranana, et présente une couverture de forêts intactes extrêmement réduite. Le travail sur le terrain a été réalisé par des bénévoles de Frontier et des chercheurs de Frontier et de l'Université d'Antsiranana. Des inventaires on été effectués pendant une année, au cours de quatre périodes d'essais qui s'étalaient chacune sur une durée de l'ordre de neuf semaines. Les inventaires sur les mammifères ont fait appel à trois méthodes, dont les lignes de trous-pièges, l'emploi de pièges Sherman et des recherches nocturnes aléatoires. Un inventaire sur les oiseaux a été compilé, utilisant la technique de la liste de recensement McKinnon.

Au cours de cette première étude détaillée portant sur cette localité, nous avons relevé la présence de 12 espèces de mammifères ainsi que la présence de 63 espèces d'oiseaux. Neuf des espèces de mammifères recensés sont endémiques à Madagascar et la plupart de ces espèces semblaient être représentées par des effectifs réduits sur la Montagne des Français au cours de la période d'étude. De toutes les espèces d'oiseaux reportées, 26 (41%) sont endémiques de Madagascar.

Afin d'évaluer l'état de conservation des mammifères et des oiseaux rencontrés à la Montagne des Français, nous avons utilisé des données recueillies au cours d'entrevues formelles et semi-formelles. Notre étude montre que les croyances locales sont dominées par des tabous ou *fady* et que ceux-ci varient selon les familles et communautés. Les pressions anthropogéniques actuelles qui pèsent sur la biodiversité sont représentées par le pâturage des zébus, la production de charbon de bois, la chasse et la culture de riz. En 2006 le massif a bénéficié d'un statut d'Aire Protégée Temporaire mais nos résultats suggèrent qu'un statut de protection permanente serait justifié. Nous proposons de poursuivre les efforts en matière de recherche et encourageons toute entreprise de développement durable qui pourrait contribuer à la conservation des ressources biologiques à l'intérieur du massif. La réussite de la protection de cette région ne pourra se faire sans la totale adhésion de l'ensemble des communautés locales.

KEYWORDS: Biodiversity, Endemism, Conservation priority areas, Montagne des Français.

MOTS CLEF: biodiversité, endémisme, aires protégées prioritaires, Montagne des Français.

INTRODUCTION

The Montagne des Français massif is situated in northern Madagascar and lies within the western dry forest domain (Humbert and Cours Darne 1965). The massif covers an area of approximately 6,114 ha and altitudes range between

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100 m and 400 m. As a result, its vegetation is of a more mesic type than that of its surroundings, and has been described as transitional between mid-altitude rainforest and dry deciduous western forest (Ramanamanjato et al. 1999).

Due to its elevation, the average annual precipitation at Montagne des Français is usually higher than that received by Antsiranana 12 km to the northwest. Antsiranana receives a mean annual rainfall of 915 mm with nine months of the year being dry (Cornet 1974). The narrow annual temperature variation (3.2 °C) is characteristic of sub-equatorial regions.

In the massif, few if any areas of primary forest remain. Most areas of forest are disturbed to some degree by agriculture and/or zebu grazing. The massif is surrounded by grassland, scrub and agricultural land, and is as a consequence, isolated from other major areas of forest in the extreme north of Madagascar (Ankarana, Analamera and Montagne d'Ambre). It has been suggested that anthropogenic deforestation is responsible for the isolation of the massif (Ramanamanjato et al. 1999) and this is unsurprising due to its position close to the provincial capital of Antsiranana.

Like many parts of Madagascar, local beliefs are dominated by taboos or *fady*. In the villages surrounding the Montagne des Français a significant proportion of the population consider it *fady* to kill lemurs but our study shows that *fady* varies within families and communities. This may in part be because some residents in the area come from as far as 750 km away.

In 2006 Montagne des Français was nominated as a Durban Vision Potential Site requiring some form of protection (Ministère de l'Environment, des Eaux et Forêts 2005) and was granted Temporary Protected Area Status (the first of three steps necessary to create a permanently protected area). Prior to this, the massif was afforded minimal official protection, which means that the exploitation of biological resources proceeded unregulated. The objectives of this article are to:

1. Highlight the biological importance of Montagne des Français;
2. Support the case for permanent protection;
3. Suggest ways in which further research and initiatives could enhance conservation of the biological resources within the massif.

METHODS

Researchers and volunteers from Frontier and the University of Antsiranana carried out fieldwork; surveys were conducted over the course of a year in four sampling periods each lasting approximately nine weeks: 7 April-15 June 2005, 28 June-5 September 2005, 5 October-14 December 2005 and 3 January-7 March 2006. Sampling periods coincided with the availabilty of volunteers to assist with the surveys. The base camp was located at E49° 22.05', S12° 19.68', close to the village of Andavakoera and adjacent to a reliable water source. The core survey area covered an area of approximately 600 ha in the immediate environs of the base camp (Figures 1 and 2).

MAMMALIAN SURVEY. Three survey methods were used:

1. Pitfall trapping. Regular deployment of pitfall traps consisting of 11 buckets 270 mm deep and 290 mm in diameter were sunk into the ground at 10 m intervals along a transect of 100 m. Generally three transects were installed at a time and checked concurrently, and each line was duplicated at three different seasons. Small holes were punched into the bottom

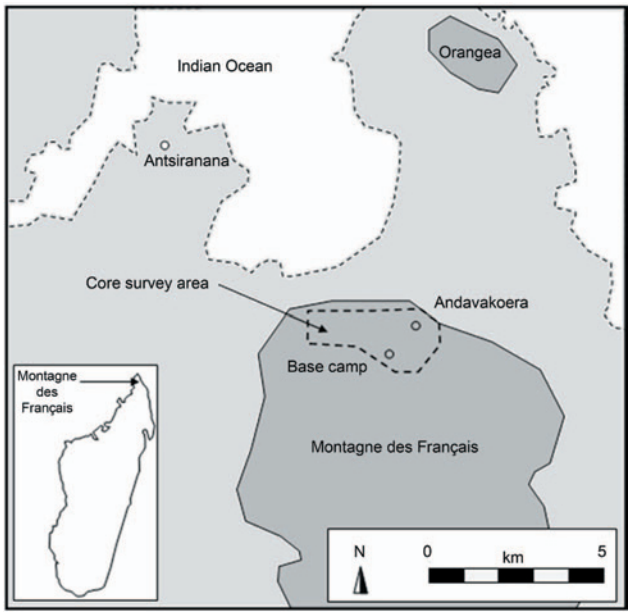

FIGURE 1. Map showing the core survey area.

of each bucket to allow water to drain. A plastic drift fence 0.5 m high was tied to thin wooden stakes and buried into the ground such that it ran across the diameter of each pitfall trap along the length of the transect. Transects were checked every morning and afternoon for a 7-8 day period. Captures were uniquely marked (by clipping fur) and released at the point of capture. A total of 12 lines duplicated three times made 36 transects carried out during the survey period in either forest or disturbed habitat.

2. Sherman trapping. Associated with each of the above transects, six sherman traps were installed as follows; two or three traps were placed in trees whilst the remainder were placed on the ground. Traps were baited with banana or peanut butter during the evening and checked for captures the following morning. Again, captures were uniquely marked and released at the point of capture. A 'trap-day' is defined as a 24-hour period (dawn to dawn) of one trap in use. A total of 1,620 trap-days were undertaken during the entire survey period and traps were in place at each location for 7-8 days (Stephenson 1994).

3. Nocturnal searches. Regular nocturnal mammal searches were undertaken using high power torches along two footpaths starting from the base camp and ending at either E49° 21.27', S12° 19.41'or E49° 20.21', S12° 20.12'. These footpaths did not coincide with any of the transects and the searches totalled 50 hours throughout the study period.

4. Incidental records. Mammal species that were observed but were not recorded using the methods above were noted as incidental observations. Nomenclature of mammals follows Goodman et al. (2003).

AVIAN SURVEY. A bird species list was compiled for Montagne des Français using the MacKinnon list census technique (MacKinnon and Phillipps 1993). A total of 110 Mackinnon lists were conducted during the study period using existing trails at dawn and dusk. The MacKinnon list method was chosen as it is recommended as a rapid assessment technique that is less susceptible to observer bias than other bird census techniques (O'Dea et al. 2004). This was important for this study as a team of researchers accompanied by varying teams of

volunteers carried out the fieldwork. The observers record a pre-determined number of species to complete one list. Thus, the unit of effort is the completion of one list. Many studies use a 10-species species list as this provides the most accurate results in species poor environments (Herzog et al. 2002, Trainor 2002, Watson et al. 2005). Species lists consisting of ten species were carried out in this study as the composition of species in the area was unknown and Malagasy avifauna is known to be relatively species poor with only 209 breeding species (Hawkins and Goodman 2003). Identification was confirmed by observation of the species; vocalizations were only used to aid observations and identification. Bird species that were observed but were not recorded using the MacKinnon list technique were noted as incidental observations. Nomenclature of birds follows Hawkins and Goodman (2003).

SOCIOECONOMIC SURVEY. A total of 25 structured interviews were carried out with residents involved in hunting from the village of Andavakoera (E49° 21.31', S12° 20.02') situated on the lower slopes of the massif (Figure 1). Interviewees were presented with a list of mammals and birds in Malagasy accompanied by photos and were asked to comment on their presence in the Montagne des Français. This list included species that had not been recorded by our study. Interviewees were all male residents of Andavakoera and ranged in age from 19 to 78 years.

In addition, 18 semi-structured interviews were undertaken with residents of the massif and Andavakoera to gain an understanding of the impacts of hunting, zebu grazing, charcoal burning and other anthropogenic activities on wildlife habitat and populations. These interviews were conducted with different people to those who answered the structured interviews. Nine of the interviewees lived within the massif but several had moved to the area from other parts of Madagascar: Ambilobe (100 km, E49° 03.03', S13° 11.45'), Vohemar (150 km, E50° 00.21', S13° 21.15'), Maroantsetra (350 km, E49° 44.21', S15° 26.15') and Moramanga (750 km, E48° 13.21', S18° 56.51'). Five women and thirteen men were interviewed with an age range from 25-75 years.

RESULTS

MAMMALS. A total of 12 mammal species were recorded in the massif during the study period (Tables 1 and 2). Three species are not native but have been introduced to Madagascar by humans, namely Black rat (*Rattus rattus*), Pygmy musk shrew (*Suncus madagascariensis*) and House mouse (*Mus musculus*). The remaining nine species are endemic to Madagascar whilst three of these are endemic to northern Madagascar, namely Crowned lemur (*Eulemur coronatus)*, Northern rufous mouse lemur (*Microcebus tavaratra)* and Northern sportive lemur (*Lepilemur septentrionalis)*. The most recent assessment of the conservation status of lemurs (Mittermeier et al. 2006) lists Aye-aye (*Daubentonia madagascariensis)* and Crowned lemur (*Eulemur coronatus)* as Vulnerable, Northern rufous mouse lemur (*Microcebus tavaratra)* as Endangered and Northern sportive lemur (*Lepilemur septentrionalis)* as Critically Endangered. The four lemur species are also listed in CITES Appendix I.

Two of the mammal species could only be identified down to the level of genus *(Eliurus* sp. and *Microgale* sp.). Many of the species encountered appeared to be present in very low numbers as sightings and / or captures over the entire study period were rare (Table 1). There were no sightings of Fat-tailed dwarf lemur (*Cheirogaleus medius)* although it has been noted in the area (Mittermeier et al. 2006).

BIRDS. A total of 63 bird species were recorded in the massif over the study period including the Madagascar crested ibis *(Lophotibis cristata)*, which is listed as Near Threatened on the IUCN Red Data List 2007 (Table 3). Of the 63 species, 26 (41%) are endemic to Madagascar.

SOCIOECONOMIC SURVEY. Structured interviews: All of the interviewees recognised the presence of the Crowned lemur (*Eulemur coronatus*) in Montagne des Français. Only 8% of the interviewees acknowledged the existence of the Aye-aye (*Daubentonia madagascariensis*) and 40% the Northern sportive lemur (*Lepilemur septentrionalis)* in the massif, respectively. None of the interviewees knew of the presence of the Northern rufous mouse lemur (*Microcebus tavaratra*). All of these latter species are cryptic and nocturnal and most locals do not spend time in the forest at night, which could explain the lack of knowledge. The only carnivore observed during the study period was the Ring-tailed mongoose (*Galidia elegans*), and 64% of the interviewees agreed with the existence of this species.

Interviewees described the presence of three mammal species not recorded during the study. All but one of the interviewees (96%) stated that the Grey bamboo lemur *(Hapalemur griseus*) is present within the massif whilst 56% and 52% respectively stated that Indian civet (*Viverricula indica*) and Fosa (*Cryptoprocta ferox*) are present.

Semi-structured interviews: A great majority (89%) of interviewees were involved in arable farming, whilst 28% were pastoralists (mainly zebu cattle). Most interviewees (78%) stated that they hunt a wide variety of animals and the remainder of interviewees contribute indirectly to demand by purchasing meat. Half of the interviewees hunt Tenrec (*Tenrec ecaudatus)* and Greater hedgehog tenrec (*Setifer setosus*); 28% hunt Madagascar crested ibis (*Lophotibis cristata*); 11% hunt Crowned lemurs (*Eulemur coronatus*) and 6% hunt Ring-tailed mongoose (*Galidia elegans*). All these species are listed on the 2007 Red List of Threatened Species. Seventeen percent of interviewees hunt African wild pig (*Potamochoerus larvatus*); however, this species was not seen during the course of the study period.

The interviewees that hunt lemurs stated that they did so using catapults and noose traps. African wild pig and Indian civet are hunted by 3-4 men at a time using spears, dogs and

FIGURE 2. View of the canyon in the core survey area. © Jeremy Sabel

TABLE 1. Capture results of small mammals obtained in pitfall lines and Sherman traps, with additional observations (* denotes native species; numbers within brackets for animals observed but not captured).

Location of trapline		Period	*Microgale* sp.*	*Setifer setosus**	*Tenrec ecaudatus**	*Microcebus tavaratra**	*Galidia elgans**	*Suncus madagascariensis*	*Eliurus* sp.*	*Mus musculus*	*Rattus rattus*
Habitat	Longitude, Latitude, Altitude										
Canyon, disturbed	E49° 20.54', S12° 19.72', 195 m	17-24 IV 2005						1			1
Canyon, disturbed	E49° 20.62', S12° 19.77', 195 m	17-24 IV 2005						1			
Canyon, disturbed	E49° 20.62', S12° 19.80', 195 m	17-24 IV 2005		1				1			1
		6-15 XI 2005									6
Steep hillside, forest	E49° 21.27', S12° 20.24', 170 m	26 IV-3 V 2005						5			2
		6-14 VII 2005									1
		15-24 X 2005									
		10-19 I 2006			1					1	
Steep hillside, forest	E49° 21.23', S12° 20.27', 185 m	26 IV-3 V 2005									
		6-14 VII 2005						2			1
		15-24 X 2005						1			
		10-19 I 2006									2
Slight hillside, forest	E49° 21.18', S12° 20.27', 185 m	26 IV-3 V 2005				(1)					1
		6-14 VII 2005									
		15-24 X 2005						1		1	3
		10-19 I 2006						1			
Valley, forest	E49° 21.44', S12° 20.86', 82 m	26 V-2 VI 2005						1		1	6
		19-28 XI 2005					(1)	3			3
Slight hillside, forest	E49° 21.44', S12° 20.97', 79 m	26 V-2 VI 2005						2		1	8
		19-28 XI 2005									4
Slight hillside, forest	E49° 21.48', S12° 21.09', 90 m	26 V-2 VI 2005	1				(1)		1		5
		19-28 XI 2005									1
Gully, forest	E49° 20.60', S12° 19.59', 232 m	29 VII-6 VIII 2005								1	4
		22-31 I 2006						2			
Slight hillside, forest	E49° 20.59', S12° 19.64', 262 m	29 VII-6 VIII 2005								2	6
		22-31 I 2006			1						
Steep hillside, forest	E49° 20.53', S12° 19.63', 288 m	29 VII-6 VIII 2005						1			2
		22-31 I 2006		1						1	
Gully, disturbed	E49° 20.7', S12° 19.58', 291 m	11-20 VIII 2005	1								5
		3-12 II 2006						1			2
Slight hillside, forest	E49° 20.22', S12° 19.72', 318 m	11-20 VIII 2005									4
		3-12 II 2006								2	3
Slight hillside, forest	E49° 20.23', S12° 19.68', 314 m	11-20 VIII 2005						1			1
		3-12 II 2006						1			1
Canyon, disturbed	E49° 20.56', S12° 19.81', 195 m	6-15 XI 2005									2
Canyon, disturbed	E49° 20.51', S12° 19.85', 195 m	6-15 XI 2005						1			3
Total number of individuals caught			2	2	2	-	-	26	1	10	78
Total number of individuals caught and observed			2	2	2	1	2	26	1	10	78

TABLE 2. Mammals recorded in Montagne des Français and not associated with pitfall lines or Sherman traps.

Taxa	Incidental observation, at E49° 22.05', S12° 19.68'				Nocturnal search at E49° 21.18', S12° 19.55'	
	7 IV-15 VI 2005	28 VI-5 IX 2005	5 X-14 XII 2005	3 I-7 III 2006	5 X-14 XII 2005	3 I-7 III 2006
O. Afrosoricida						
Tenrecidae						
Setifer setosus	8		3	8		
Tenrec ecaudatus			8	22		
O. Primata						
Cheirogaleidae						
Microcebus tavaratra	2	2	1	1		
Lemuridae						
Eulemur coronatus	23	27	13	21		
Megalapidae						
Lepilemur septentrionalis					2	2
Daubentoniidae						
Daubentonia madagascariensis				1		
O. Carnivora						
Eupleridae						
Galidia elegans	1		1	1		
O. Rodentia						
Nesomyidae						
Eliurus sp.	1					
Total number of species observed	5	2	5	6	1	1

wooden traps. Tenrecs are hunted by 1-2 people and dogs; hunting ceases in January when the tenrecs produce young. Birds are hunted using nooses, catapults and nets. One interviewee stated that he caught parrots by using maize as bait and placing glue on the perch and another stated that he uses poisoned maize to kill parrots and Madagascar crested ibis and takes care to remove the stomach.

Half of the interviewees stated that it is *fady* to kill African wild pig (*Potamochoerus larvatus*) whereas 44 % stated that it is *fady* to kill Crested drongo (*Dicrurus forficatus*), Pied crow (*Corvus albus*) and owls. In addition a third of interviewees stated that it is *fady* to kill lemurs.

The majority of interviewees (72 %) stated that they harvest wood from the massif and 22 % sell it for profit, mostly in Antsiranana. A similar number (78 %) of interviewees stated that they are involved in charcoal production and 67 % sell it for financial gain.

DISCUSSION

Within the Montagne des Français lemur species benefit from the belief among some locals that it is *fady* to kill lemurs. Neither the Aye-aye (*Daubentonia madagascariensis*), the Northern sportive lemur (*Lepilemur septentrionalis*) nor the Northern rufous mouse lemur (*Microcebus tavaratra*) appear to be hunted and few of the interviewees knew of their existence within Montagne des Français.

The Northern sportive lemur *(Lepilemur septentrionalis*) is considered Critically Endangered by Mittermeier et al. (2006). This genus is among the most hunted lemurs in Madagascar (Olivieri et al. 2005, Scheumann et al. 2007) due to its conspicuous sleeping sites and its tendency to hide rather than flee when disturbed. The Northern rufous mouse lemur (*Microcebus tavaratra)* is considered Endangered by Mittermeier et al. (2006). This species was described in 2000 by Rasoloarison et al., and has a highly clumped distribution.

Crowned lemur (*Eulemur coronatus)* were recorded frequently during the study period, perhaps due to its diurnal habits and tendency to give alarm calls. In addition a third of interviewees (33 %) stated that it is *fady* to kill lemurs. Therefore, we conclude that hunting pressure seems to be low for the crowned lemur (*Eulemur coronatus,* classified as Vulnerable by Mittermeier et al. (2006)).

Northern sportive lemur (*Lepilemur septentrionalis*), Northern rufous mouse lemur (*Microcebus tavaratra)* and Crowned lemur (*Eulemur coronatus)* all have highly clumped distributions in the northern part of Madagascar and are protected only in Montagne d'Ambre National Park and Ankarana, Analamera, and Forêt d'Ambre Special Reserves. Habitat loss and fragmentation is of particular concern for the Aye-aye (*Daubentonia madagascariensis*) because it has a large home range and low natural population densities compared to other lemurs (Mittermeier et al. 2006). This species occurs in numerous protected areas in Madagascar but has been assessed as being Vulnerable by Mittermeier et al. (2006).

Of the nine endemic species of mammal recorded during the study period, six were encountered on less than ten occasions during the study period and we consider that these species (Aye-aye *Daubentonia madagascariensis*, Northern sportive lemur *Lepilemur septentrionalis*, Northern rufous mouse lemur *Microcebus tavatra*, Ring-tailed mongoose *Galidia elegans*, Tuft-tailed rat *Eliurus* sp. and Shrew tenrec *Microgale* sp.), in addition to the Crowned lemur (*Eulemur coronatus*) are of conservation importance in the Montagne des Français. When combined with the eight species of bats recorded

TABLE 3: Species list of the avifauna observed in the Montagne des Français.
Abbreviations: Status (Hawkins & Goodman 2003). B=Breeding, I=Introduced, M=Migrant and E = endemic * = listed as near threatened on the IUCN Red Data List 2007. CITES I = listed in Appendix 1, II = Listed in Appendix 2.

Vernacular name	Scientific name	Status	CITES
Squacco heron	*Ardeola ralloides*	B	
Cattle egret	*Bubulcus ibis*	B	
Madagascar crested ibis*	*Lophotibis cristata*	E	
Fulvous whistling duck	*Dendrocygna bicolor*	B	
Yellow-billed kite	*Milvus aegyptius*	B	
Madagascar harrier-hawk	*Polyboroides radiatus*	E	II
Frances's sparrowhawk	*Accipiter francesii*	B	II
Madagascar buzzard	*Buteo brachypterus*	E	II
Madagascar kestrel	*Falco newtoni*	B	II
Eleonora's falcon	*Falco eleonorae*	M	II
Peregrine falcon	*Falco peregrinus*	B	I
Helmeted guineafowl	*Numida meleagris*	I	
Madagascar buttonquail	*Turnix nigricollis*	E	
White-throated rail	*Dryolimnas cuvieri*	B	
Madagascar turtle dove	*Streptopelia picturata*	B	
Namaqua dove	*Oena capensis*	B	
Madagascar green pigeon	*Treron australis*	B	
Greater vasa parrot	*Coracopsis nigra*	B	II
Lesser Vasa Parrot	*Coracopsis vasa*	B	II
Gray-headed lovebird	*Agapornis cana*	E	II
Madagascar lesser cuckoo	*Cuculus rochii*	M,B	
Crested coua	*Coua cristata*	E	
Madagascar coucal	*Centropus toulou*	B	
Western scops owl	*Otus madagascariensis*	E	II
Madagascar long-eared owl	*Asio madagascariensis*	E	II
Collared nightjar	*Caprimulgus enarratus*	E	
Madagascar nightjar	*Caprimulgus madagascariensis*	B	
African palm swift	*Cypsiurus parvus*	B	
Alpine swift	*Apus melba*	B	
African black swift	*Apus barbatus*	B	
Madagascar malachite kingfisher	*Alcedo vintsioides*	B	
Madagascar pygmy kingfisher	*Ispidina madagascariensis*	E	
Madagascar bee-eater	*Merops superciliosus*	B	
Broad-billed roller	*Eurystomus glaucurus*	M,B	
Madagascar hoopoe	*Upupa marginata*	E	
Madagascar bush lark	*Mirafra hova*	E	
Mascarene martin	*Phedina borbonica*	B	
Madagascar wagtail	*Motacilla flaviventris*	E	
Ashy cuckoo-shrike	*Coracina cinerea*	B	
Madagascar bulbul	*Hypsipetes madagascariensis*	B	
Long-billed tetraka	*Bernieria madagascariensis*	E	
Madagascar magpie-robin	*Copsychus albospecularis*	E	
Stonechat	*Saxicola torquata*	B	
Madagascar brush warbler	*Nesillas typica*	B	
Common newtonia	*Newtonia brunneicauda*	E	
Madagascar cisticola	*Cisticola cherina*	E	
Common jery	*Neomixis tenella*	E	
Madagascar paradise flycatcher	*Terpsiphone mutata*	B	
Souimanga sunbird	*Nectarinia souimanga*	B	
Long-billed green sunbird	*Nectarinia notata*	B	
Madagascar white-eye	*Zosterops maderaspatana*	B	
Red-tailed vanga	*Calicalicus madagascariensis*	E	
Hook-billed vanga	*Vanga curvirostris*	E	
Sickle-billed vanga	*Falculea palliata*	E	
Chabert's vanga	*Leptopterus chabert*	E	
Blue vanga	*Cyanolanius madagascarinus*	B	
Crested drongo	*Dicrurus forficatus*	B	
Pied crow	*Corvus albus*	B	
Common mynah	*Acridotheres tristis*	I	
Madagascar starling	*Hartlaubius auratus*	E	
Sakalava weaver	*Ploceus sakalava*	E	
Madagascar fody	*Foudia madagascariensis*	E	
Madagascar mannikin	*Lonchura nana*	E	

by Robinson et al. (2006), a total of 20 mammal species have been recorded within the Montagne des Français. However, four mammal species mentioned during the course of interviews were not recorded during the surveys: Grey bamboo lemur (*Hapalemur griseus),* Fosa (*Cryptoprocta ferox)*, Indian civet (*Viverricula indica)*, and African wild pig (*Potamochoerus larvatus)*. They are thought to have been present within the massif until recently and may still be present at low population densities. Fosa (*Cryptoprocta ferox)* is listed as Endangered on the 2007 Red List of Threatened Species and Grey bamboo lemur (*Hapalemur griseus)* is considered as Critically Endangered by Mittermeier et al. (2006).

Several bird species observed are listed on CITES Appendix I or II (see Table 3) and are species that are subject to the international pet trade, such as birds of prey, lovebirds, and parrots (CITES 2007).

The Madagascar crested ibis (*Lophotibis cristata*) is hunted by 28% of the interviewees and is listed as near threatened on the 2007 Red List due to declining numbers as a result of, on one hand, the reduction and loss of area and quality of habitat in which it lives, and on the other hand due to hunting. The presence of Fulvous-whistling duck (*Dendrocygna bicolor*) and Squacco heron (*Ardeola ralloides*) is thought to be due to the proximity of mangrove habitat. The level of endemism of birds within the Montagne des Français (41%) is unexceptional in a Malagasy context, i.e. relatively low, given that 51% of breeding bird species are endemic to the island (Hawkins and Goodman 2003).

Despite the anthropogenic pressures on the habitats within the Montagne des Français, the topography of the massif has afforded it some degree of protection while the matrix surrounding it has been degraded. The relatively small size of the Montagne des Français and its ecological insularity is a major cause for concern because the massif may

no longer support viable populations of species with large home ranges such as Aye-aye (*Daubentonia madagascariensis)* and Fosa (*Cryptoprocta ferox)* (Ancrenaz et al. 1994). Connectivity with other semi-natural areas such as the dry forest at Orangea 8 km to the north (Figure 1) is desirable to allow the exchange of individuals within subpopulations (Hawkins and Racey 2005).

It is clear that whilst local households rely on natural resources for livelihoods, they are directly contributing to the degradation of the forest ecosystems of the Montagne des Français. Amongst others, charcoal production and cattle grazing seem to be the predominant threats within the massif. Charcoal is produced for personal use and for resale in Antsiranana and consequently many of the more accessible areas within the massif have been cleared for this purpose. Also, larger areas of the lower slopes have been cleared to enable zebu cattle to graze; zebus were observed by the authors penetrating as far as the base camp. The harvesting of wood for resale also has a detrimental effect on biodiversity but we think that the pressure from this activity may have eased since the area was selectively logged for valuable timber 30 years ago. The hydrology and topography of the massif are such that cultivation of rice and other crops is not an extensive activity and hence does not have a significant negative impact on the biodiversity of the massif.

Hunting is a widespread activity, which is a major pressure on the fauna of the massif with many bird and mammal species considered as potential targets. Five of the species (one bird and four mammals) currently hunted are listed on the 2007 Red List. According to our findings, the Madagascar crested ibis (*Lophotibis cristata*) seems to be present at very low population densities. Therefore we consider the hunting pressure to be great enough to extirpate this bird from the massif in the near future. On the other hand, a significant proportion of inhabitants do not hunt lemurs as it is considered *fady*, and as such the Montagne des Français has an important role to play in the conservation of lemurs in northern Madagascar.

Previous studies have proved that the Montagne des Français is an important centre of endemism for plants, invertebrates, amphibians and reptiles (Pintak and Böhme 1988, Glaw et al. 2001, Lavranos et al. 2001, Glaw et al. 2005a,b, Andriamampianina et al. 2000, Lourenço and Goodman 2006, D'Cruze et al. 2007). The results presented in this paper along with those presented by Robinson et al. (2006) and D'Cruze et al. (2007) show that the Montagne des Français is an important biodiversity hotspot, and together they provide strong support to the case for permanent formal protection.

FURTHER INITIATIVES. In this section we suggest opportunities for conservation and development initiatives, which could enhance the protection of the biological diversity within the Montagne des Français through the alteration of patterns of natural resource use amongst the local community. Sustainability in conserving this area will only be achieved if the local communities are fully engaged in a participatory process, and if their livelihood is secured. Furthermore, the following modest list of initiatives shall also help the cause of recommending this region as a Permanent Protected Area:

- Development efforts to improve human health conditions through initiatives such as the provision of hygiene information and mobile health clinics;
- Implementation of conservation education at school and community level;
- Formulation of a long-term management plan for the massif involving the local communities, NGOs and ANGAP;
- Improvement of structural ecological connectivity with other semi-natural habitats such as Orangea 8 km to the north;
- Development of alternative forms of income for local communities such as community based ecotourism.

In addition, there are opportunities for further research into the biological resources of the massif. The following list of tasks could provide valuable support to the case for a Permanent Protected Area:

- Search for signs of Grey bamboo lemur (*Hapalemur griseus)* and Fosa (*Cryptoprocta ferox)*;
- Identification of *Eliurus* sp. and *Microgale* sp.
- Identification of ring-tailed mongoose (*Galidia elegans)* to subspecies level.

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Parasites gastro-intestinaux de *Microcebus murinus* de la forêt littorale de Mandena, Madagascar

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RÉSUMÉ

Ce travail avait pour but de décrire les parasites gastro-intestinaux du lémurien *Microcebus murinus* de la forêt littorale fragmentée de Mandena et d'évaluer l'analyse des parasites basée sur des échantillons de fèces. Des matières fécales au nombre de 427 provenant de 169 individus de *M. murinus* vivant dans cinq fragments de forêt ont été analysées. Trois individus de *M. murinus* ont été sacrifiés et autopsiés en vue d'une identification des vers parasite qui ont pondu chaque type d'œuf trouvé dans les excréments et afin de voir leurs localisations dans le tube digestif de l'animal. *Microcebus murinus* héberge neuf espèces de parasites gastro-intestinaux dont six nématodes avec une espèce non-identifiée d'Ascarididae, une espèce de Subuluridae du genre *Subulura*, une espèce de l'ordre des Strongylida et du genre *Trichuris* (Trichuridae), deux espèces d'Oxyuridae dont l'une est du genre *Lemuricola* et l'autre reste encore non-identifiée, deux cestodes appartenant au genre *Hymenolepis* (Hymenolepididae) et un protozoaire de l'ordre des Coccidia. Comparés à toutes les études déjà faites auparavant sur les parasites gastro-intestinaux de *M. murinus*, les parasites hébergés par les microcèbes de Mandena appartiennent à d'autres espèces que celles qui étaient déjà connues pour infester cette espèce de lémurien. De cette étude, je suggère que le nombre d'œufs et de larves de *Subulura* sp. trouvés dans les matières fécales pourrait refléter l'intensité de l'infestation des microcèbes par cette espèce de parasite.

ABSTRACT

So far parasitological studies were concentrated on large primates such as apes and monkeys. This is probably due to epidemiological interest because apes, which are genetically closer to humans, are known to be a reservoir of certain pests and diseases fatal to humans and vice versa. Prosimian gastrointestinal parasites are less studied. The goal of this project was to assess and describe the gastro-intestinal parasites of the lemur species *Microcebus murinus* from the littoral forest fragments of Mandena, southeastern Madagascar. In addition I wanted to evaluate the utility of determining gastro-intestinal parasite loads based on fecal samples. From April 2003 to October 2005, a total of 427 fecal samples from 169 different individuals of *M. murinus* from five forest fragments were analyzed to assess the parasite species richness of this lemur species based on parasite larvae and egg morphology. Three individuals of *M. murinus* were also sacrified in order to look for adult worms for identification and confirmation of parasite species, and to localize their gastro-intestinal parasites in the digestive tract. Screening all fecal samples by using the modified technique of the McMaster flotation, I noted that *Microcebus murinus* harbored nine different forms of intestinal parasites, and six of them were nematodes: a member of the Ascarididae family, one species of the Subuluridae family represented by the genus *Subulura*, an unidentified Strongylida, a species of the genus *Trichuris* (Trichuridae), two forms of the Oxyuridae family, one from the genus *Lemuricola* and the other still unidentified. For the Plathelminthes, two cestodes of the genus *Hymenolepis* (Hymenolepididae) were found and one species of Protozoa, belonging to the Coccidia order. These gastro-intestinal parasites of *M. murinus* from Mandena have not been described as parasites of *M. murinus* yet. The cestode infection of this lemur deserves special attention because no study has reported lemurs infected by cestodes up to now. Adult worms of the *Trichuris* species were found in the caecum. I localized *Lemuricola* worms in the caecum and large intestine. *Subulura* worms were more abundant in the caecum than in the small and large intestine. A large number of *Subulura* larvae has been observed in the caecum. As exemplified by the data on *Subulura* sp. worms in the digestive tract of *M. murinus*, the number of nematode parasite eggs and larvae found in the feces are correlated with the intensity of infection in the digestive tract.

MOTS CLEF : *Microcebus murinus*, infestation parasitaire, morphologie, nématodes, cestodes, protozoaires.
KEYWORDS: *Microcebus murinus*, parasites, lemurs, primates, Nematoda, Cestoda, Protozoa.

INTRODUCTION

Madagascar est connu comme l'un des pays les plus riches en biodiversité dans le monde avec un taux d'endémicité très élevé (Mittermeier et al. 2004). Cette biodiversité concerne toutes les catégories du vivant, y compris les parasites. Or ces derniers peuvent affecter la survie et la reproduction de l'hôte par des effets pathologiques et indirectement par modification des

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conditions physiologiques de l'hôte (Chandra et Newberne 1977, Boyce 1990, Dobson et Hudson 1992, Hudson et al. 1992, Coop et Holmes 1996). Une sévère parasitose peut provoquer une hémorragie, une immuno-dépression, un avortement spontané chez les femelles, des malformations congénitales chez le jeune et des décès (Chandra et Newberne 1977, Despommier et al. 1995). Pour une meilleure protection de la biodiversité, il est important de considérer l'étude des agents pathogènes dont les parasites.

Beaucoup d'études ont été faites sur les parasites gastro-intestinaux des singes sauvages d'Afrique (McGrew et al. 1989, Ashford et al. 1990, 2000, Lilly et al. 2002), des babouins également en Afrique (Appleton et al. 1986, Eley et al. 1989, Müller-Graf et al. 1997, Hahn et al. 2003) et des singes hurleurs américains (Stuart et al. 1990, 1998, Stoner 1996). Les parasites gastro-intestinaux affectant les autres taxons de primates restent cependant moins connus (Stuart et al. 1993, Gillespie et al. 2004, 2005). Baer (1935) a fait des études sur quelques helminthes de lémuriens et d'autres auteurs ont aussi déployé des efforts pour étudier les parasites gastro-intestinaux de ces primates, mais surtout sur les nématodes (ex. Chabaud et Choquet 1955, Chabaud et Brygoo 1956, Chabaud et Petter 1958, 1959, Chabaud et al. 1961a, 1961b, 1964, 1965, Petter et al. 1972). Hugot, Morand, Gardner et Baylac ont spécifiquement orienté leurs travaux de recherche sur la phylogénie des oxyures (Nematoda) des lémuriens (Hugot 1998, Hugot et Baylac 2007, Hugot et al. 1995, 1996). Randriamiadamanana (1998) et Rasambainarivo (2008) ont aussi réalisé des études sur les parasites des lémuriens mais celles-ci ont été effectuées sur des animaux en captivité dans des parcs zoologiques. Irwin et Raharison (soumis) ont résumé l'état actuel de nos connaissances sur les parasites de lémuriens. Peu d'études ont inventoriés les parasites de lémuriens vivant en liberté (Junge et Louis 2002, 2005, 2007, Junge et Sauther 2006, Raharivololona 2006, Raharivololona et al. 2007, Schwitzer et al. soumis).

Dans la présente étude, j'ai examiné les parasites gastro-intestinaux de *Microcebus murinus* vivant en totale liberté dans la forêt littorale de Mandena. Le but était d'inventorier, de décrire et de localiser toutes les espèces de parasites gastro-intestinaux (helminthes et protozoaires) infestant cet animal et aussi d'examiner si l'infestation parasitaire pouvait être mesurée par le nombre d'œufs et de larves présents dans les matières fécales. L'objectif de ce travail n'était pas de procéder à une étude morphologique complète des parasites mais de fournir les caractères significatifs appréciables sur les échantillons en vue d'une diagnose. La première partie de cet article correspond à une mise à jour des identifications préliminaires des parasites de microcèbes déjà publiées (Raharivololona 2006) et dans la deuxième partie je présente une corrélation entre l'infestation parasitaire et le nombre d'œufs et de larves dans les matières fécales.

MATÉRIELS ET MÉTHODES

ESPÈCE ÉTUDIÉE. *Microcebus murinus* est un petit lémurien nocturne pesant 60 g environ (Rasoloarison et al. 2000). Il est arboricole et omnivore. Sa nourriture est composée d'invertébrés, de fruits, de fleurs, de gommes, de nectar et de petits amphibiens et reptiles. L'animal cherche sa nourriture en solitaire mais il dort en groupe pendant le jour (Mittermeier et al. 2006).

SITE D'ÉTUDE. Cette étude a été effectuée dans la forêt littorale fragmentée de Mandena qui se trouve à 12 km au nord-est de Tolagnaro (Fort-Dauphin), dans le sud-est de Madagascar. L'altitude du site est comprise entre 0 et 20 m, centré sur le point 47° 00' E, 24° 57' S. La forêt est sempervirente avec des arbres de 10 à 15 m de hauteur et un sous-bois dense. La pluviométrie annuelle est de 1540 mm en moyenne dans les zones à proximité de Tolagnaro et la saison sèche est difficile à distinguer. Les différents fragments de forêt sont numérotés de M1 à M20. Les captures ont été faites dans les cinq fragments M5, M13, M15, M16 et M20 (Ganzhorn et al. 2007, Vincelette et al. 2007) (Figure 1).

CAPTURE DES ANIMAUX. Les captures ont été faites à l'aide de pièges Sherman utilisés dans les parcelles permanentes pré-établies dans les différentes zones d'étude en suivant les procédures standard (Ramanamanjato et Ganzhorn 2001). Les pièges étaient appâtés d'une tranche de banane et installés dans 40 ou 50 localités dans chaque parcelle permanente des cinq fragments de forêt pendant quatre nuits successives par mois. Dans chaque localité, deux pièges ont été posés dont un sur le sol et un autre ficelé sur une branche d'arbre à 1,5 m au dessus du sol. Tous les animaux capturés ont été mesurés, pesés, sexés et marqués avec un transpondeur sous-dermique. Ils ont ensuite été relâchés à l'endroit même de leur capture.

Les périodes de capture se sont déroulées d'avril à octobre 2003, en mai 2004, de mi-octobre à mi-novembre 2004 et de juillet à octobre 2005. Petra Lahann, Nina Rüdel et Jörg Schüller ont fourni d'autres échantillons provenant d'animaux capturés entre novembre 2003 et mars 2004, ainsi qu'en juin et en juillet 2003.

PRÉSERVATION DES MATIÈRES FÉCALES ET IDENTIFICATION DES PARASITES. Les fèces fraîchement expulsées par les animaux dans les pièges, dans les sacs ou aux endroits où ils ont été libéré, ou encore pendant toutes les opérations réalisées sur eux (mesure, pesée, etc.) ont été collectées et préservées dans des tubes contenant du formol à 4%. La technique de flottaison de McMaster modifiée (Sloss et al. 1994) a été utilisée pour les analyses coprologiques qualitatives et quantitatives car c'est une méthode classique pour évaluer le nombre de vers (ex. Gulland et al. 1993, Paterson et al. 1998, Coltman et al. 1999, Cassinello et al. 2001). Pour cela, 300 mg de matières fécales ont été triturées et mélangées avec 4,5 ml de solution d'iodure de potassium dont la densité est de 1,5 g/ml. Cette méthode est une procédure standard déjà utilisée (Meyer-Lucht et Sommer 2005, Schad et al. 2005). Après avoir filtré le mélange avec une passoire à petite maille, nous avons pris la solution recueillie à l'aide d'une pipette et rempli les deux cellules de la lame de Mc Master. Avec l'objectif x10 du microscope, nous avons compté le

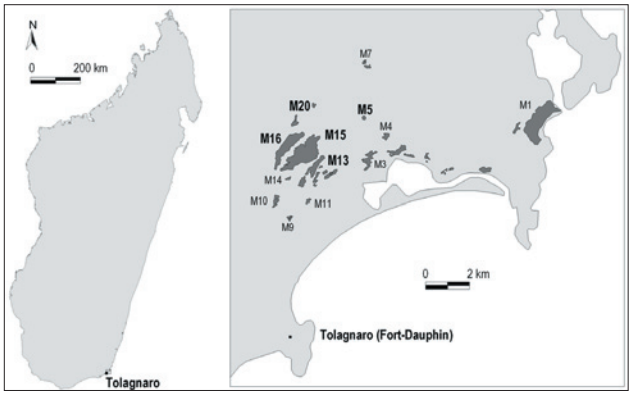

FIGURE 1. Sites d'études au sud-est de Madagascar.

nombre de chaque type d'œuf de parasite et de larves présents dans les deux cellules. Les œufs, larves et oocystes ont été mesurés avec un oculaire micrométrique et photographiés à différents grossissements (x100, x400, x600). L'identification des parasites est fondée sur la morphologie, la taille, la structure interne des œufs et des oocystes. Elle a été faite en se référant aux travaux de Chabaud et Petter (1958, 1959), Chabaud et ses collaborateurs (Chabaud et al. 1964, 1965), Hugot et ses collaborateurs (Hugot et al. 1996) et d'Euzéby (1981). Je tiens à signaler qu'actuellement, toutes mes collections (microcèbes et vers parasites) sont déposées au Laboratoire de Primatologie et de Biologie Évolutive, Département d'Anthropologie et de Biologie Évolutive, Université d'Antananarivo, Madagascar.

DISTINCTION ENTRE VRAIS PARASITES ET PARASITES ACCIDENTELS. Comme *Microcebus murinus* vit dans la forêt, il peut être continuellement infesté par des parasites d'autres animaux qui vivent en sympatrie avec lui, de sorte que certains des parasites mentionnés ci-dessus pourraient être des parasites accidentels. Pour appréhender cette question, j'ai procédé à l'expérience suivante. Quelques individus (connus pour être infestés par plusieurs espèces de parasites après les analyses coprologiques) ont été isolés dans des cages pendant quatre nuits successives, avec un seul animal par cage, pour pouvoir distinguer les vrais parasites des parasites accidentels de l'animal. Toutes les précautions avaient été prises pour minimiser les risques de contamination de l'animal venant de l'extérieur. Les fèces produites par l'animal pendant la nuit ont été collectées pour une analyse coprologique. Mais avant tout, un examen de la durée du passage des aliments dans le tube digestif de *M. murinus* était nécessaire, de sorte que nous avons coloré en rouge les tranches de banane avant de les donner à l'animal le soir vers 2000h. En contrôlant les cages très tôt le matin (vers 0500h), les boules de fèces évacuées par l'animal pendant la nuit étaient colorées en rouge. La même opération a été répétée la deuxième nuit en donnant à l'animal des bananes non colorées. Aucune trace de colorant rouge n'a plus été observée sur les excréments évacués pendant la deuxième nuit. Il est donc certain que le passage des aliments dans le tube digestif de *M. murinus* dure moins de 24 heures. De ce fait, nous avons pu conclure qu'à partir de la deuxième nuit de captivité, tous les œufs présents dans les matières fécales de l'animal pouvaient être considérés comme appartenant à un vrai parasite de l'animal.

Après toutes les analyses coprologiques il est plus que probable que les œufs observés à plusieurs reprises dans les matières fécales appartiennent à de vrais parasites de l'animal.

RECONNAISSANCE DES VERS PARASITE. L'identification des parasites est plus fiable si on se base sur les caractères des vers adultes. Grâce à l'autorisation (n° 157 /MINENV.EF/SG/DGEF/DPB/SCBLF/RECH du 13 juillet 2005) délivrée par le Ministère de l'Environnement, des Eaux et Forêts Malgache, je me suis résignée à sacrifier trois individus de *Microcebus murinus* dans la forêt de Mandena, seule alternative permettant une identification des vers parasites dans leurs tubes digestifs. Pour cela, parmi les animaux tenus en captivité pendant quatre nuits successives, trois ont été sacrifiés dont les matières fécales contenaient des œufs de plusieurs espèces de parasite. Ces trois individus avaient été capturés en 2005, respectivement le 23 juillet dans la parcelle M16, le 2 août dans la parcelle M13 et le 10 août dans la parcelle M15.

Après ouverture de la partie ventrale de l'animal, nous avons enlevé le tube digestif complet et ficelé ses deux extrémités pour éviter la fuite des vers ou des larves. Il a été ensuite conservé dans de l'alcool à 70 ° pour être analysé au laboratoire. Il a été sectionné en sept parties pour déterminer la localisation des vers, depuis l'œsophage, l'estomac, l'intestin grêle, le gros intestin, le cæcum, le côlon jusqu'au rectum. Chaque ver collecté dans les différentes sections a été monté entre lame et lamelle en y versant quelques gouttes de solution de Lactophénol d'Aman pour permettre une identification sous le microscope. Avec l'analyse des matières fécales de l'animal déjà faite sur le terrain et en se référant à la littérature, nous avons pu attribuer les œufs aux espèces de parasites.

Je tiens à signaler que les œufs observés à plusieurs reprises dans les matières fécales ont aussi été considérés comme appartenant à de vrais parasites de l'animal, même en l'absence de vers lors de l'autopsie des trois animaux, car certaines espèces de parasites sont connues pour migrer dans les muqueuses intestinales (Euzéby 1981).

ANALYSE STATISTIQUE. Le nombre d'œufs et de larves par gramme de matière fécale est le nombre de ces derniers trouvés dans les deux cellules de la lame de Mc Master multiplié par 50. Le test de corrélation de Spearman dans SPSS 9.0 a été utilisé pour étudier la corrélation entre le nombre de vers femelles trouvés dans les tubes digestifs et le nombre de leurs œufs et larves dans un gramme de fèces.

RÉSULTATS

Neuf espèces de parasites gastro-intestinaux ont été recensées chez les *Microcebus murinus* vivant dans la forêt littorale de Mandena, à savoir huit helminthes et une espèce de protozoaire. L'helminthofaune comprend six nématodes dont une espèce non-identifiée d'Ascarididae, *Subulura* sp., une espèce de l'ordre des Strongylida, un *Trichuris* sp., deux espèces d'Oxyuridae du genre *Lemuricola* pour l'une et d'un genre non identifié pour l'autre ainsi que deux espèces de cestodes appartenant au genre *Hymenolepis*. Le protozoaire est une coccidie. La taxinomie d'Anderson (2000) a été utilisée pour classifier les nématodes et celle d'Euzéby (1981) pour les cestodes. La systématique de Neveu-Lemaire (1942) a été adoptée pour classifier les protozoaires.

DESCRIPTION DES PARASITES GASTRO-INTESTINAUX

NEMATODA

Ordre Ascaridida

Famille Ascarididae

Genre non identifié

Espèce non identifiée

Des œufs d'Ascarididae ont été recensés dans les matières fécales. L'espèce n'a pas encore été identifiée à cause de l'absence de vers adultes dans le tube digestif des animaux autopsiés et par manque de références bibliographiques portant sur le sujet.

Œufs : Les œufs sont dépourvus d'ornements polaires et ne renferment pas un embryon vermiforme mais une morula qui ne remplit pas la totalité de la coque. Ils sont généralement ellipsoïdaux et rarement ronds. La coque est épaisse et mamelonnée. Toutes ces structures sont des caractéristiques de la famille des Ascarididae. Les formes ellipsoïdales présentent quelques fois une inégalité des pôles. Les œufs sont de couleur marron et mesurent 28–65 µm / 20–45 µm (Figure 2).

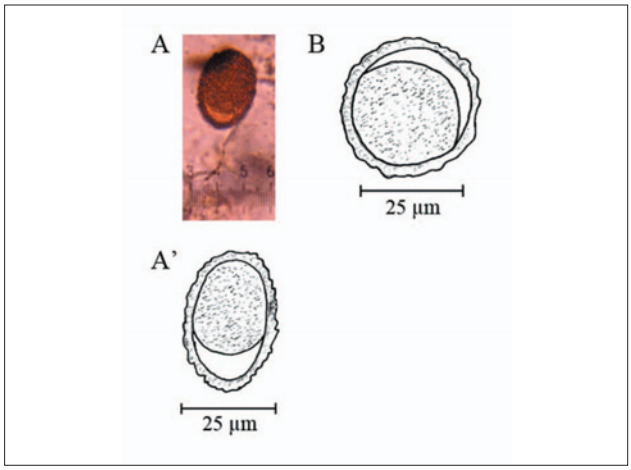

FIGURE 2. Œufs d'un Ascarididae non identifié (Nematoda) de couleur marron et une taille de 28–65 µm / 20–45 µm ; A photographie ; A', B schémas.

Ordre Ascaridida
Famille Subuluridae
Genre *Subulura*
Espèce non identifiée

Ce sont des petits vers blancs. Certaines caractéristiques morphologiques rappellent l'espèce *Subulura baeri* décrite par Chabaud et al. (1965) comme la bouche circulaire un peu plus grande que le diamètre interne de la capsule buccale, une capsule buccale circulaire mais avec une hauteur de 35 µm, un diamètre interne de 30 µm et un diamètre externe de 60 µm, des lobes périphériques des pièces pharyngées et des lobes chordaux dépourvus de dents et disposés en forme d'hélice, et enfin une absence d'ailes cervicales. Quelque fois des vers entiers de *Subulura* sp. étaient évacués dans les fèces des microcèbes.

Les trois individus de *M. murinus* sacrifiés sont infestés par *Subulura* sp. Cette espèce de parasite se localise dans l'intestin grêle, le cæcum et le gros intestin (Tableau 1).

La plus forte concentration des vers se trouve dans le cæcum. On en a aussi récolté dans l'intestin grêle et le gros intestin mais en plus faible nombre. Une présence massive de larves de *Subulura* sp. a aussi été observée dans le cæcum.

Mâle : La dimension du corps est de 9 à 12,3 mm de long et 250 à 290 µm de large (largeur maximale). L'œsophage est long d'environ 1 mm. Il existe un bulbe œsophagien plus large que le corps de l'œsophage. L'anneau nerveux et le pore excréteur se situent respectivement à 150 µm et 375 µm de l'apex. La distance entre le centre de la ventouse et le cloaque est de 325 µm. La distance ventouse-pointe caudale est de 650 µm. La queue mesure 275 µm de long. Les deux spicules sont inégaux; l'un mesure 375 µm et l'autre 510 µm (Figure 3A).

Femelle : La taille du corps est comprise entre 10 et 16,5 mm de long, et 370 et 510 µm de large (largeur maximale). La longueur de l'œsophage est de l'ordre de 1,5 mm. L'anneau nerveux, le pore excréteur et la vulve se trouvent à 170 µm, 400 µm et 5,5 mm de l'apex. La queue est longue de 1 mm (Figures 3B,C).

Œufs : Les œufs sont embryonnés. La coque est lisse et possède deux membranes dont l'extérieure peut s'altérer. La forme générale des œufs est ovoïde ou arrondie. La taille des œufs est de 50-85 µm / 45-70 µm (Figure 3D).

Ordre Strongylida
Famille inconnue
Genre non identifié
Espèce non identifiée

Je n'ai pas vu de vers adultes dans les tubes digestifs mais seulement des œufs dans les excréments. Comme il est difficile d'identifier les espèces de Strongylida en se basant sur les caractères des œufs, j'ai laissé l'identification au niveau de l'ordre dans la classification de ce parasite.

Œufs : Les œufs possèdent les caractéristiques générales des œufs de Strongylida, sans ornements et avec un embryon vermiforme, ils sont régulièrement ovoïdes, rarement ellipsoïdes, la coque est lisse et mince. Cette dernière présente parfois l'apparence d'une double membrane, les pôles sont larges et égaux ; et l'embryon est plus ou moins développé. Les œufs sont longs de 40 à 75 µm et larges de 25 à 45 µm (Figure 4).

Ordre Enoplida
Famille Trichuridae
Genre *Trichuris*
Espèce non identifiée

Des vers adultes de ce genre de parasite ont été trouvés dans le tube digestif d'un microcèbe. Ils sont reconnaissables par la partie rétrécie du corps plus mince et plus longue que la partie élargie, le mâle à extrémité caudale enroulée et pourvu d'un spicule enveloppé d'une gaine.

L'ouverture du tube digestif d'un microcèbe autopsié nous a permis d'identifier la localisation de ce parasite dans

TABLEAU 1. Localisation des vers adultes de *Subulura* sp. dans le tube digestif de *Microcebus murinus* et infestation des animaux.

N° d'identification de *M. murinus*	Sexe	Date de capture	Fragments	Localisation des vers	Nombre de vers mâles	Nombre de vers femelles	Nombre total de vers
00-0633-B614	Mâle	2 VIII 2005	M13	Intestin grêle	1	3	4
				Cæcum	8	27	35
				Gros intestin	3	9	12
Nombre total des vers					12	39	51
00-0611-9347	Mâle	10 VIII 2005	M15	Cæcum	40	145	185
				Gros intestin	2	3	5
Nombre total des vers					42	148	190
00-0214-4A21	Femelle	23 VII 2005	M16	Intestin grêle	0	2	2
				Cæcum	105	262	367
				Gros intestin	3	8	11
Nombre total des vers					108	272	380

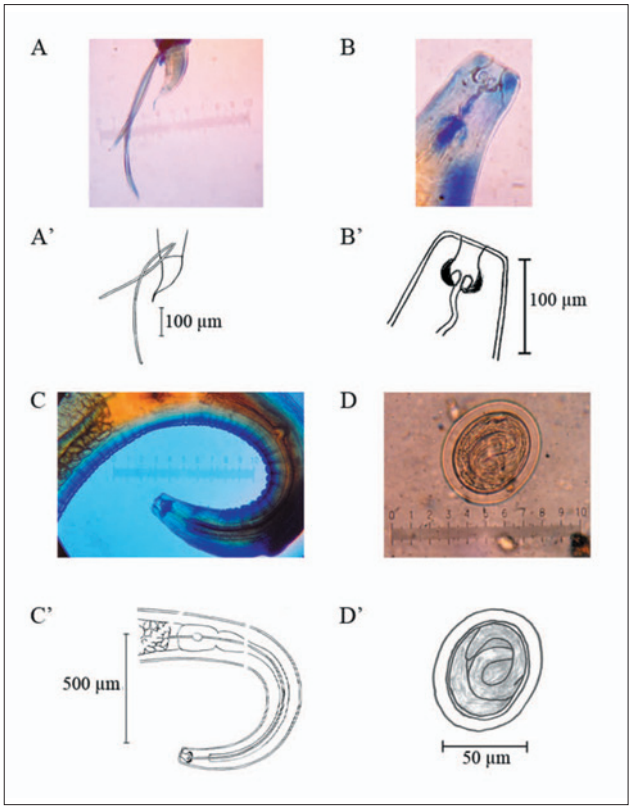

FIGURE 3. *Subulura* sp. (Nematoda) : A spicules du mâle (photographie) ; A' spicules du mâle (schéma) ; B tête de la femelle, vue latérale (photographie) ; B' tête de la femelle, vue latérale (schéma) ; C extrémité antérieure de la femelle, vue latérale (photographie) ; C' extrémité antérieure de la femelle, vue latérale (schéma) ; D œuf (photographie) ; D' œuf (schéma).

le cæcum. Cet individu est un mâle adulte capturé le 10 août 2005 dans le fragment M15 et identifié sous le numéro 00-0611-9347. L'infestation de l'animal est très faible car on n'a vu que trois individus de *Trichuris* sp. dans l'intestin de l'animal dont un mâle adulte et deux femelles adultes.

Mâle : Nous avons pris les mesures principales qui nous donnent une longueur totale d'environ 25 mm, une longueur de la région œsophagienne de 14 mm, une longueur de l'arrière-corps de 11 mm, un rapport entre la longueur de l'œsophage et celle de l'arrière corps de 1,27. La largeur du corps est de 30 µm au niveau de la tête, de 190 µm à la fin de l'œsophage, de 405 µm à l'arrière-corps (la partie la plus large du corps) et de 75 µm à l'extrémité caudale. La longueur du spicule est de 1 mm et sa largeur à la base de 50 µm (Figure 5A).

Femelle : Les mensurations de la femelle donne une longueur totale d'environ 27 mm, une longueur de la région œsophagienne de 16,5 mm, une longueur de l'arrière corps de 10,5 mm, un rapport entre la longueur de l'œsophage et celle de l'arrière-corps de 1,57. La largeur du corps est de 35 µm au niveau de la tête, de 200 µm à la fin de l'œsophage, de 475 µm à l'arrière corps (largeur maximale) et de 175 µm à l'extrémité caudale. La longueur de l'utérus est de 6,25 mm et la distance entre la vulve et le début de l'intestin de 150 µm (Figure 5B).

Œufs : Les œufs ne sont pas segmentés et sont pourvus de deux bouchons polaires transparents et saillants. La coque est lisse et les deux côtés sont très convexes. L'œuf est de couleur marron et mesure 80-100 µm / 38-44 µm (Figure 5C).

Ordre Oxyurida
Famille Oxyuridae
Genre *Lemuricola*
Espèce non identifiée

Des vers de ce genre de parasite ont été observés dans le tube digestif d'un individu mâle adulte et d'une femelle adulte de microcèbe. Les vers ont été reconnus par la queue très effilée et très longue de la femelle, la bouche triangulaire limitée par trois petites lèvres, l'œsophage pourvu d'une dilatation prébulbaire et d'un bulbe subsphérique valvulé et la présence d'une vésicule cuticulaire céphalique.

Chez le microcèbe mâle, capturé le 10 août 2005 dans le fragment M15 et portant le numéro 00-0611-9347, j'ai trouvé une femelle de *Lemuricola* sp. dans le cæcum et deux femelles de *Lemuricola* sp. dans le gros intestin. Chez le microcèbe femelle, capturé le 23 juillet 2005 dans le fragment M16 et identifié sous le numéro 00-0214-4A21, j'ai collecté une femelle de *Lemuricola* sp. dans le gros intestin (Tableau 2).

Femelle : Le corps est blanc et long d'environ 0,9 mm à 1,5 mm. Sa largeur maximale est comprise entre 90 µm et 180 µm. Les autres mensurations faites sur le corps sont la longueur totale de l'œsophage de 200 µm avec un corpus de 145 µm, l'isthme de 5 µm et le bulbe de 50 µm. L'anneau nerveux, le pore excréteur et la vulve se situent respectivement à 50 µm, 250 µm et 400 µm de l'apex. L'extrémité antérieure présente une vésicule céphalique striée dans sa portion postérieure. La queue est longue de 220 µm (Figures 6A,B).

Œufs : Les œufs sont non embryonnés. La coque est lisse, fine et à double membrane. Les deux pôles ne présentent pas d'ornementation polaire, sont égaux et étroits. Les deux côtés sont convexes. Les œufs sont oblongs, symétriques avec une taille de 75-105 µm/30-45 µm (Figure 6C).

Ordre Oxyurida
Famille Oxyuridae
Genre non identifié
Espèce non identifiée

Des œufs appartenant probablement à une autre espèce d'Oxyuridae ont aussi été décelés dans les matières fécales de *M. murinus*. Ce parasite reste encore non identifié car on n'a vu ni des vers adultes ni des larves dans les tubes digestifs des animaux sacrifiés.

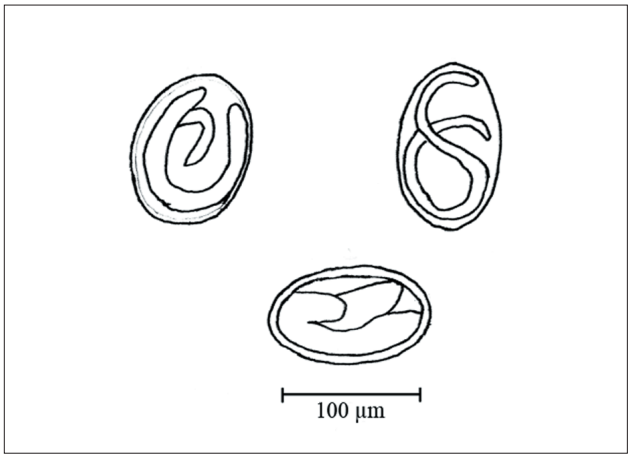

FIGURE 4. Œufs d'un Strongylida (Nematoda) de 40 à 75 µm x 25 à 45 µmschémas de trois œufs différents.

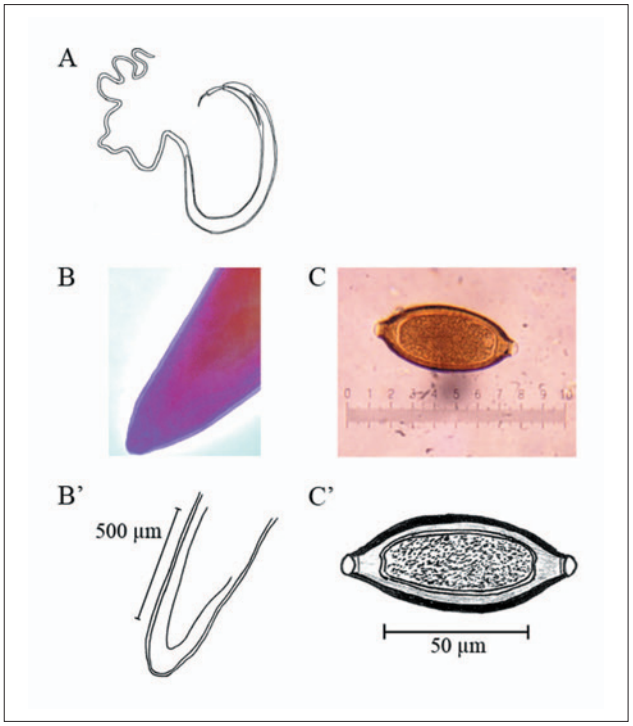

FIGURE 5. *Trichuris* sp. (Nematoda) : A mâle (schéma) ; B extrémité postérieure de la femelle (photographie) ; B' extrémité postérieure de la femelle (schéma) ; C œuf (photographie) ; C' œuf (schéma).

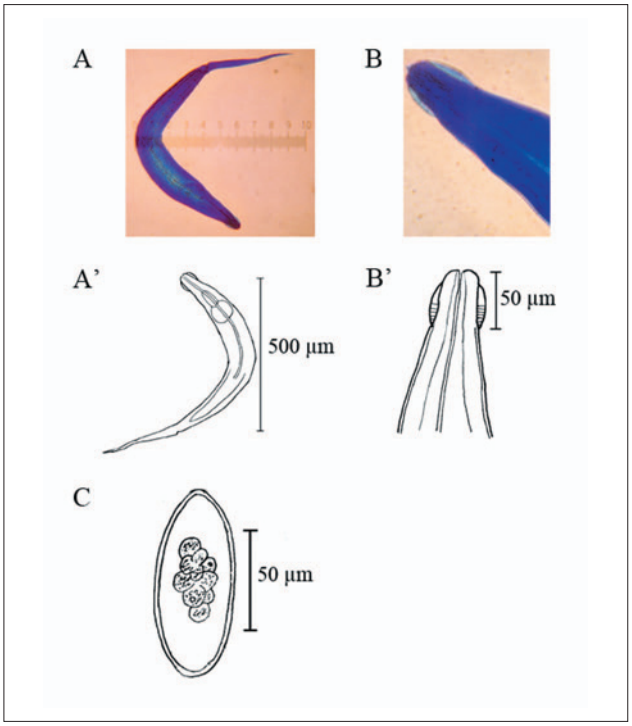

FIGURE 6. *Lemuricola* sp. (Nematoda) : A femelle (photographie), A' femelle vue latérale (schéma) ; B tête de la femelle (photographie) ; B' tête de la femelle (schéma) ; C' œuf (schéma).

Œufs : Les œufs ne possèdent pas d'ornements polaires et ils ne sont pas embryonnés. Ils sont constitués par une morula ou des blastomères, qui ne remplissent pas la totalité des œufs, à l'intérieur. La coque est lisse avec une seule membrane ou apparemment plutôt une double membrane. Les deux pôles sont étroits et égaux. Les œufs sont ovoïdes et asymétriques (l'un des deux côtés est aplati ou légèrement convexe, caractéristique des œufs d'Oxyuridae). Ils sont de couleur marron clair et mesurent 60-80 µm / 20-40 µm (Figure 7).

CESTODA

Les vers récoltés dans les tubes digestifs de *M. murinus* appartiennent au genre *Hymenolepis* car ils possèdent un rostre qui est probablement rétractile, des ventouses lisses, des pores génitaux unilatéraux et des proglottis toujours plus larges que longs du scolex jusqu'à la partie terminale du ver.

Ordre Cyclophyllidea
Famille Hymenolepididae
Genre *Hymenolepis*
Espèce non identifiée (sp1)

Quatre vers d'*Hymenolepis* sp1 ont été récoltés dans l'intestin grêle du microcèbe mâle adulte n° 00-0633-B614, capturé le 2 août 2005 dans le fragment M13. Ils sont de couleur blanche et mesurent 3 à 3,3 cm de long et 1,4 à 1,7 mm de large (largeur maximale). Les vers possèdent un petit rostre. Le scolex est très petit avec des ventouses circulaires dépourvues de crochets. Le cou est invisible, soit très court et rétractile ou complètement absent. Les proglottis sont toujours plus larges que longs du scolex jusqu'à l'extrémité postérieure du ver. Le long du corps, la taille des anneaux varie de 30 à 250 µm de long et 300 µm à 1,7 mm de large. Les premiers anneaux sont très courts, les suivants sont beaucoup plus larges que longs et les derniers sont plus ou moins étroits (Figure 8A). Quelquefois des fragments d'*Hymenolepis* sp1 étaient évacués dans les fèces des microcèbes.

Œufs : L'œuf contient un embryon hexacanthe dont les 6 crochets se positionnent par paires. La coque est peu épaisse et lisse. La présence des filaments polaires n'est pas très nette. Les œufs sont généralement ellipsoïdes et de couleur vert clair. Ils ont une longueur de 55 à 70 µm et une largeur de 35 à 55 µm (Figure 8B).

Ordre Cyclophyllidea
Famille Hymenolepididae
Genre *Hymenolepis*
Espèce non identifiée (sp2)

C'est un cestode brun très clair, long d'environ 11 cm et large de 0,3 cm. Un seul individu a été trouvé dans l'intestin grêle du microcèbe femelle adulte n° 00-0214-4A21, capturé

TABLEAU 2. Localisation des vers adultes de *Lemuricola* sp. dans le tube digestif de *Microcebus murinus* et infestation des animaux.

N° d'identification de *M. murinus*	Sexe	Date de capture	Fragments	Localisation des vers	Nombre de vers mâles	Nombre de vers femelles	Nombre total de vers
00-0611-9347	Mâle	10 VIII 2005	M15	Cæcum	0	1	1
				Gros intestin	0	2	2
00-0214-4A21	Femelle	23 VII 2005	M16	Gros intestin	0	1	1

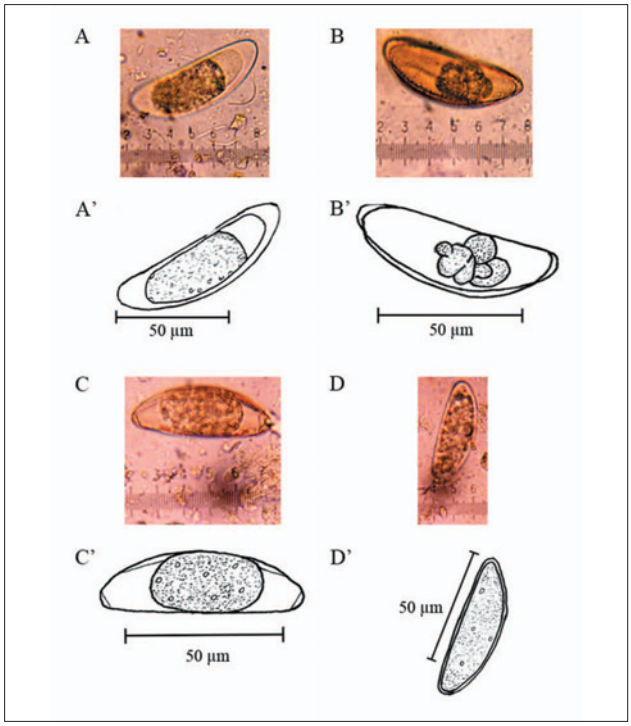

FIGURE 7. Oxyuridae (Nematoda) : A – D œufs d'Oxyuridae d'espèces différentes ou de la même espèce mais à des stades différents (photographies) ; A' – D' œufs d'Oxyuridae d'espèces différentes ou de la même espèce mais à des stades différents (schémas).

le 23 juillet 2005 dans le fragment M16. Il est à signaler que le ver occupait pratiquement le diamètre de l'intestin grêle. Le scolex est très petit et globuleux. Il est pourvu d'un rostre demi-sphérique et possède des ventouses circulaires lisses. Le cou est très long et mince par rapport au scolex. Les anneaux sont toujours plus larges que longs du scolex à la partie terminale du ver. Comme *Hymenolepis* sp1, les premiers proglottis sont très courts ; les suivants s'agrandissent progressivement en largeur et en longueur tout en restant plus larges que longs et en se rétrécissent dans la partie postérieure du ver (Figures 9A,B,C).

Œufs : L'œuf possède un embryon hexacanthe et les six crochets se placent deux à deux à l'intérieur. Il est dépourvu de filaments polaires. La coque est lisse et très épaisse car elle est constituée d'une double membrane. Les œufs sont arrondis, de couleur marron foncé et mesurent 50 à 70 µm de diamètre (Figure 9D).

PROTOZOA
Ordre Coccidia
Famille non identifiée
Genre non identifié
Espèce non identifiée

L'oocyste présente les caractéristiques d'un coccidie avec un protoplasme granuleux renfermant partiellement ou entièrement l'intérieur de l'oocyste et forme ovoïde ou sphérique. Ces oocystes ont une coque lisse et mince. Ils possèdent deux membranes. Ils sont de couleur marron et de taille 10-30 µm/ 10-25 µm (Figure 10).

CORRÉLATION ENTRE L'INFESTATION PARASITAIRE ET LE NOMBRE D'ŒUFS ET DE LARVES DANS LES MATIÈRES FÉCALES. Pour étudier cette corrélation, je n'ai pu considérer que *Lemuricola* sp. et *Subulura* sp. car seules ces deux espèces de parasite se sont avérées infester plus

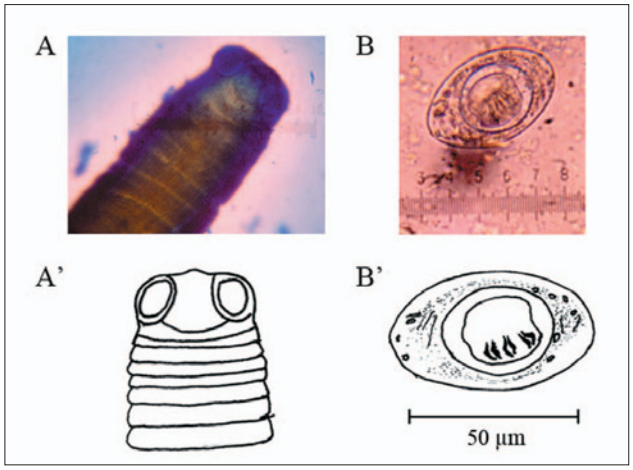

FIGURE 8. *Hymenolepis* sp1 (Cestoda) : A adulte, photographie scolex et fragment de strobile ; A' adulte, schéma scolex et fragment de strobile ; B œuf (photographie) ; B' œuf (schéma).

d'un individu sur les trois microcèbes sacrifiés (Tableau 3). Même si le test statistique montre qu'il existe une parfaite corrélation positive entre le nombre de vers femelles de *Subulura* sp. trouvés dans les tractus digestifs des trois microcèbes et le nombre d'œufs et de larves évacués par ces derniers dans chaque gramme de matière fécale (coefficient de corrélation de Spearman $r_s = 1$; $P < 0,05$; $N = 3$), il me semble délicat de généraliser trop vite cette observation car elle correspond au résultat d'une seule étude. Si le parasite a un cycle saisonnier, on peut imaginer des fluctuations dans l'année. On sait aussi que l'hôte peut influencer la ponte de ses parasites. Cette étude suggère donc que cette corrélation peut exister. Par contre, aucune association n'a été constatée entre les deux variables chez *Lemuricola* sp.

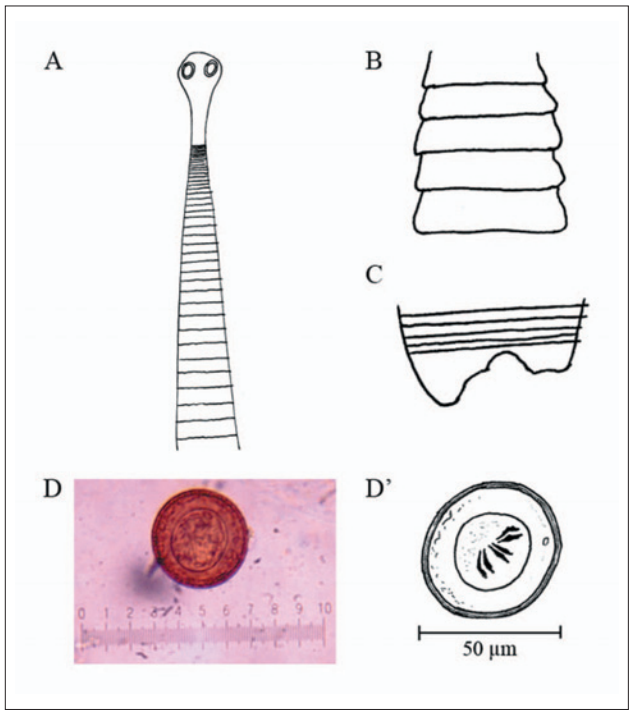

FIGURE 9. *Hymenolepis* sp2 (Cestoda) : A adulte (schéma) ; B Fragment de strobile (schéma) ; C Extrémité postérieur (schéma) ; D œuf (photographie); D' œuf (schéma).

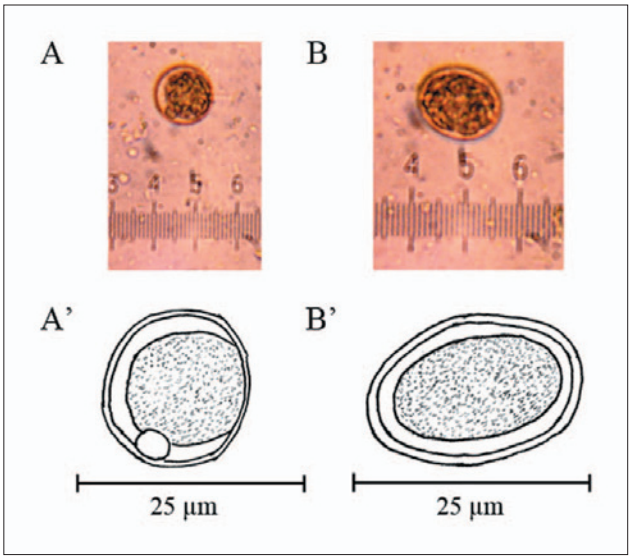

FIGURE 10. Oocystes de Protozoa, Coccidia. A, B formes différentes (photographies) ; A' B' (schémas).

DISCUSSION

L'espèce non identifiée d'Ascarididae (Ascaridida) : je pense que cette espèce, que j'ai isolée mais pas encore identifiée, n'est pas *Ascaris petiti* connu pour infester *Daubentonia madagascariensis* par Chabaud et ses collaborateurs en 1964 car ce parasite semble être spécifique de cette espèce de lémurien (Chabaud et al. 1964).

Subulura sp. (Ascaridida, Subuluridae) : d'après les différentes mensurations faites sur les vers, l'espèce de *Subulura* des microcèbes de Mandena pourrait être différente de *Subulura baeri* décrite par Chabaud et al. en 1965 chez *Microcebus murinus* d'Ampijoroa et de *Subulura otolicni* trouvée chez *Cheirogaleus* sp. (Chabaud et Petter 1958). Les mesures effectuées sur les spécimens de Mandena sont plus petites que celles des deux autres à part la longueur de la queue du mâle et la largeur maximale du corps de la femelle. Le caractère le plus frappant est que les deux spicules des mâles des spécimens de Mandena sont inégaux alors que ceux des deux autres sont égaux.

D'après cette étude, on pourrait suggérer qu'il existe une corrélation positive entre le nombre de vers femelles de *Subulura* sp. trouvés dans le tractus digestif et le nombre de leurs œufs et larves évacués dans un gramme de matière fécale. Mais vu le nombre trop faible des animaux sacrifiés, la probabilité d'existence d'un cycle saisonnier chez ce parasite et de l'influence de l'hôte sur la ponte de ses parasites, il est difficile d'affirmer que l'intensité de l'infestation de *Subulura* sp. chez *Microcebus murinus* peut être mesurée par le nombre d'œufs et de larves présents dans un gramme de fèces. L'espèce non identifiée de Strongylida : comme les œufs de Strongylida se ressemblent entre eux, il était difficile d'identifier cette espèce de parasite. Les espèces de Strongylida connues pour infester les lémuriens sont *Lemurostrongylus residuus* chez *Hapalemur griseus* (Chabaud et al. 1961a) et *Pararhabdonema longistriata* chez *Avahi laniger* (Kreis 1945), *Lepilemur ruficaudatus* (Chabaud et Choquet 1955), *Indri indri* (Chabaud et al. 1961a), *Lepilemur microdon, Varecia variegata, Eulemur fulvus, Eulemur albifrons, Propithecus coquereli* et *Avahi occidentalis* (Chabaud et al. 1965).

Trichuris sp. (Enoplida, Trichuridae) : en 1965, Chabaud et ses collaborateurs ont recensé *Trichuris lemuris* chez *Cheirogaleus major, Lemur macaco albifrons, Lemur macaco fulvus, Lemur mongoz, Lemur catta* et *Daubentonia madagascariensis* mais jamais chez *Microcebus murinus*. Le mâle de *Trichuris* sp. que j'ai observé est plus grand (25 mm/405 µm) que celui rencontré chez *Cheirogaleus major* (17,5 mm/300 µm) et la femelle est plus petite (27 mm/475 µm) que la femelle de *Trichuris lemuris* rencontrée chez *Daubentonia madagascariensis* (36 mm / 680 µm) (Chabaud et al. 1964). Dû au manque de références bibliographiques et au petit nombre de vers que nous avons collectés, nous ne pouvons pas affirmer que l'espèce de *Trichuris* chez *M. murinus* est *T. lemuris* bien qu'en considérant les différentes mensurations prises sur les vers, il est aussi probable que cette espèce de parasite des microcèbes de Mandena n'est autre que *T. lemuris*.

Lemuricola sp. (Oxyurida, Oxyuridae) : d'après la taille des vers, il est fort probable que l'espèce de *Lemuricola* de *Microcebus murinus* de la forêt de Mandena est différente des deux espèces de *Lemuricola* (*Lemuricola microcebi* et *Lemuricola* sp.) décrites par Hugot et ses collaborateurs en 1995 et de *Lemuricola contagiosus* décrit par Chabaud et Petter (1959). La femelle de *L. microcebi* mesure de 2,57 mm à 2,94 mm de long, celle de *L. contagiosus* a une longueur comprise entre 2,81 mm et 3,45 mm et la femelle de *Lemuricola* non identifiée par l'équipe de Hugot a une longueur de 2,23 mm à 2,55 mm. Les vers que j'ai récoltés sont plus courts.

Les œufs d'Oxyuridae ne se mélangent pas au bol fécal, ils restent tapissés sur le bord interne de l'anus (Euzéby 1981). L'inexistence de corrélation entre le nombre de vers femelles de *Lemuricola* sp. trouvés dans les tubes digestifs des microcèbes et le nombre de leurs œufs et larves dans un gramme de matière fécale pourrait être due à ce fait, ou à la taille réduite des échantillons, ou probablement à la périodicité de la ponte de cette espèce de parasite.

L'espèce non identifiée d'Oxyuridae (Oxyurida) : étant donné que *Microcebus murinus* a un régime alimentaire plutôt insectivore (Martin 1972, Mittermeier et al. 2006), il n'est pas surprenant de trouver des espèces de parasite à cycle évolutif

TABLEAU 3. Corrélation entre le nombre de vers femelles de *Lemuricola* sp., *Subulura* sp. trouvés dans les tubes digestifs et le nombre de leurs œufs et larves évacués dans un gramme de matière fécale.

Espèces de parasite	Numéro des individus infestés	Nombre de vers femelles	Nombre d'œufs et de larves par gramme de matière fécale
Subulura sp.	00-0633-B614	39	150
Subulura sp.	00-0611-9347	148	550
Subulura sp.	00-0214-4A21	272	1000
Lemuricola sp.	00-0611-9347	3	0
Lemuricola sp.	00-0214-4A21	1	50

indirect comme les Oxyuridae, dont l'hôte intermédiaire est probablement un insecte, dans leur fèces.

En comparant la forme et la taille des œufs du premier genre d'Oxyuridae (*Lemuricola*) sus-mentionné avec celles de ce dernier, une différence a été constatée. Le premier a un pôle plus large et une taille plus grande que le second. Les œufs de cette deuxième espèce d'Oxyuridae ressemblent à ceux des espèces de *Lemuricola* décrites par Chabaud et ses collaborateurs (1965). Il est alors probable que ces œufs appartiennent aussi au genre *Lemuricola*, mais tant qu'on n'a pas trouvé de vers adultes dans les tubes digestifs des animaux sacrifiés, il est plus prudent de maintenir l'identification au niveau de la famille dans la classification car il est difficile d'identifier les parasites à partir des œufs seulement.

Cestoda et Protozoa : il est important de mentionner qu'aucune recherche n'a signalé l'infestation de *Microcebus murinus* par des cestodes et des coccidies. Les espèces d'*Hymenolepis* ne sont probablement ni *H. nana*, ni *H. diminuta.*

En 1965, l'équipe de Chabaud a identifié trois espèces de parasites gastro-intestinaux chez *Microcebus murinus* avec *Subulura baeri* (Ascaridida, Subuluridae),
Spirura diplocyphos (Spirurida, Spiruridae) et *Rictularia lemuri* (Spirurida, Rictulariidae). Hugot et ses collaborateurs (1995) ont découvert *Lemuricola microcebi* (Oxyurida, Oxyuridae). Dans cette étude, j'ai recensé neuf autres espèces. Cette étude est donc une extension des recherches déjà faites auparavant sur les parasites des lémuriens. Aucune espèce de Spirurida n'a été décelée chez les microcèbes de Mandena.

Les trois espèces de parasites gastro-intestinaux décrites par Chabaud et ses collaborateurs (1965) proviennent de *Microcebus murinus* de différentes localités autres que Tolagnaro, à savoir *Subulura baeri*, *Spirura diplocyphos* chez *Microcebus murinus* d'Ampijoroa et *Rictularia lemuri* chez *Microcebus murinus murinus* de la région de Manakara. Hugot et al. (1995) ont trouvé *Lemuricola microcebi* chez *Microcebus murinus* en provenance des environs de Toliara. La systématique des microcèbes était encore confuse à l'époque. Actuellement, les espèces de microcèbes qui vivent à Ampijoroa sont *Microcebus ravelobensis* et *Microcebus murinus* (Zimmermann et al. 1998). Les microcèbes vivant aux alentours de Toliara sont *M. murinus* dans la forêt de Beza Mahafaly, Zombitse, Vohimena et Vohibasia, et *M. griseorufus* dans la forêt de Beza Mahafaly et Lamboharana (Rasoloarison et al. 2000). Le microcèbe vivant dans la région de Manakara est *Microcebus rufus*. Il est nécessaire de mentionner cette biogéographie des microcèbes car je n'ai pas vu les espèces de parasite décelées par Chabaud et ses collaborateurs dans les matières fécales de *M. murinus* de la forêt de Mandena. Il semble y avoir une variation géographique de la communauté des parasites qui pourrait être spécifique pour chaque espèce d'animal. Dans ce cas, l'identification des parasites pourrait aussi contribuer à la classification des espèces animales. Plusieurs auteurs ont déjà mis en évidence que les oxyures des primates sont spécifiques pour chaque espèce de primate (Cameron 1929, Sandosham 1950, Inglis 1961, Brooks et Glen 1982, Hugot et al. 1996, Hugot 1998).

Comme *Microcebus murinus* partage le même habitat que beaucoup d'espèces animales (lézards, caméléons, oiseaux…), il n'est pas surprenant de trouver des œufs des parasites de ces derniers dans leurs fèces. L'animal pourrait les ingérer accidentellement par contamination de leur nourriture via les excréments de ces animaux. J'ai trouvé des œufs d'*Enterobius* sp. (Oxyurida, Oxyuridae) dans les fèces de *M. murinus*, connu comme vrai parasite d'autres espèces de lémuriens (Chabaud et al. 1965) ; des œufs d'Heligmosominés (Strongylida, Heligmonellidae) qui ressemblent aux œufs d'Heligmosominés de *Rattus rattus* et un œuf de Trematoda (chez un seul microcèbe), connu pour infester les escargots.

La fragmentation de la forêt augmente sa fréquentation par les villageois riverains et les animaux domestiques. Le passage fréquent de l'Homme dans la forêt de Mandena pourrait expliquer la présence des œufs d'*Ascaris* sp. dans les matières fécales de *Microcebus murinus* (Raharivololona 2006). Quelques fois, les microcèbes descendent sur le sol. Ils sont alors exposés à une variété de parasites venant de l'Homme ou d'autres espèces terrestres. Ceci pourrait expliquer la présence d'œufs probablement d'Acanthocephala dans les fèces de deux individus de microcèbe. Ce parasite contamine les cochons (Euzéby 1981) qui passent fréquemment dans cette forêt.

CONCLUSION

Neuf espèces de parasites gastro-intestinaux ont été recensées chez *Microcebus murinus* dans la forêt de Mandena. Il s'agit probablement de nouvelles espèces de parasites infestant ce petit lémurien nocturne. Cette étude suggère que l'infestation parasitaire par *Subulura* sp. pourrait être mesurée par le nombre d'œufs et de larves trouvés dans un gramme de matière fécale. Elle est une extension des travaux déjà effectués par beaucoup d'auteurs sur les parasites des lémuriens. Il est souhaité d'appliquer la génétique moléculaire dans l'identification exacte des espèces de parasites et aussi d'étudier l'impact du parasitisme sur l'hôte car certains parasites sont connus pour être fatals pour certains animaux.

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INTERVIEW MADAGASCAR CONSERVATION & DEVELOPMENT

Conservation in times of political turmoil – the Madagascar Fauna Group Perspective

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Journal MCD:
"Not only people are suffering from 2009 political turmoil, but also natural resources are under higher pressures than usual. How do you envision your future efforts in the conservation of Madagascar? Will it be rather a mitigation approach, or would there be also a chance for a more proactive approach in order to prevent similar pressures in the future?"

Even under normal circumstances, it remains a tough job to keep conservation high on the priority list in Madagascar. Being one of the poorest nations worldwide, this biodiversity hotspot is facing irreversible impacts by current and increasing environmental crime – facilitated by this period of political instability leading to lawlessness and limited law enforcement. While it may not be obvious at first sight, Madagascar's biodiversity is one of its most precious riches. Every single human being depends directly and indirectly on all marine, freshwater and terrestrial ecosystems for daily life. For example, people rely on their forests to prevent erosion, to provide oxygen, to protect watersheds, to purify water and air, to control diseases and pests, to give a home to many pollinators and seed dispersers of important fruiting trees and agricultural crops, to eat, build and cook…and for many more ecological services. Current logging and poaching will result in long-term economic damage to the valuable ecotourism industry that Madagascar was developing. Sadly this reality is not yet widely understood.

Madagascar Fauna Group has invested continuously in a multi-faceted approach to conservation for the past 20 years. The MFG's goal is to conduct applied research of the forest ecosystem in all its different facets, to reach a better understanding on how to consequently improve protection and management of the Betampona Nature Reserve in collaboration with Madagascar National Parks, as well as to conserve and restore the Ivoloina Forestry Station in collaboration with the Ministry of the Environment, Forestry and Tourism. In addition to directly focusing on research and conservation, MFG prioritizes environmental education and capacity building programs for our local partners, with a strong emphasis on sustainable natural resource management, agro-forestry and conservation medicine. Through our education and training programs, MFG hopes to plant seeds that will give rise to new generations of well informed Malagasy 'conservation ambassadors'. Therefore, we target a broad group of stakeholders, ranging from primary school children to university students, and including local decision makers and farmers. In addition, we organize events such as World Environment Day celebrations, the Environmental Circuses, and award ceremonies for our Forest Restoration Project, trying to attract wide audiences. On a more continual basis, we try to make an impression on our 15,000 annual visitors – of which the majority are Malagasy – with several take-home conservation messages throughout Parc Ivoloina. We will reinforce these messages in a weekly environmental transmission on the local radio Vonio in Tamatave, for six months beginning June 2009.

MFG believes in combining both a mitigating and prompt reactive approach in direct response to urgent environmental events along with a proactive approach where we promote positive change for long-term quality of life and natural resource protection. For example, we have intensified our patrols in Betampona Reserve, ensuring continuous presence to discourage illegal activities. Also we collaborate with Missouri Botanical Garden to create a safety net collection of endangered plant species, and we contribute to wildlife conservation though captive breeding programs at Ivoloina Zoo. On the other hand, we hope to increase alertness and responsiveness to environmental problems, by widely advocating environmental messages, by increasing understanding of nature's role in everyone's daily life, and by encouraging local communities to participate in forest restoration to create a protective buffer around Betampona. At the same time, MFG offers practical training in commercial plant cultivation and in alternative, less destructive and sustainable agroforestry methods. This 'consciousness' at the local level is amplified towards national level when joining forces with other fellow conservation NGOs in-country. Together we can get out stronger and more powerful messages, which have the potential to influence conservation strategies designed by the transition and future government. Our efforts need not end there, as there will always be a demand for precious hardwood, rare wildlife and minerals – a demand that comes mainly from abroad, driving the ecological degradation on a larger scale. The traditional but also the newly emerging economic powers that drive this process at the receiving end of the supply-demand chain must also be sensitized and controlled through international legislation and conventions (e.g. CITES), and they should be encouraged

strongly to operate through regulated and certified sustainable timber and wildlife trade.

Madagascar Fauna Group, being a small grassroots NGO that works mainly at the local level, does not have the ambition nor is in the position to make systemic changes at the national level. However we can function as a local environmental watchdog by reporting on what is happening on the ground and by alerting those in power to take action. Moreover by always operating as a good example of biodiversity conservation together with key local partners to promote conservation and sustainable development, we can make a difference locally and hopefully inspire many more on a broader scale to follow the same path!

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

LA CRISE, NOUS L'AVONS CONNUE AVANT VOUS : HABITS DÉCHIRÉS, PIEDS NUS MAIS SOURIRE AUX LÈVRES !

Landy Rabemanantsoa

(The turmoil, we experienced it before you did: torn clothes, naked feet but a smile on our faces!)

OLONA TSY KIVY FA MANANA FANANTENANA IZANY.

Haja

(Courage et espoir pour la vie)

(Courage and hope for life)

TONGA DIA HITA FA AHATANY AN-TANANA IO SARY IO- NY OLONA ANY NA DIA MANAMBOLA TSA DIA TAITRA AMINA HAINGO- ALEO HANGONINY AVADIKA OMBY.

Hery, Fianarantsoa-Betsileo ta-tsimo-

(Je reconnais la région Sud de Betsileo – Les gens là-bas, même s'ils sont riches, ne sont pas attirés par la « mode » - Économiser pour le cheptel bovin, c'est leur devise)

I recognize southern Betsileo – Even if people are not rich they are not attracted by fashion, their main point is 'use your savings to increase the cattle herd'

OLONA RERAKA AVY NIASA, HAMONJY FODIANA, FARITRA BETSILEO ILAY TOERANA, MITONDRA LAMBA KELY- TRANO AKAIKY AMBALAVAO, TANY TSARA RANO (MISY DOME VATO BE), HITA TARATRATRA NY FOMBA FIAIIANA, TRANO BIBY FIOMPY MIARAKA AMIN'NY TANANA, HITA TARATRA NY FOMBA HISAFIDIANANY NY HANORENANA TANANA (VATO BE METY MIARO AMIN'NY RIVOTRA, MISY RANO MANDEHA,.....).

Fidy

(Scène dans la région de Betsileo montrant des hommes au retour des travaux de champs. Leur façon de s'habiller (le port de lamba sur les épaules) rappelle la région d'Ambalavao. Le lieu ou ils ont implanté leur village ne manque pas d'eau – le dôme ou inselberg semble retenir la bise)

Scene in the Betsileo area showing farmers coming back from work in the fields. Their way of dressing (having the lamba on the shoulders) indicates the region of Ambalavao. The place where they established their village does not lack for water (the dome or inselberg in the background seems to protect from the wind)

TANTSAHA SAHIRANA AVY NIASA TENY AN-TSAHA, LANAKY NY ASA ANGAHA ARY HAMONJY FODIANA DIA TOA MAKA AINA, TSY KIVY NA DIA MAFY AZA NY ONJAM-PIAINANA.

Fara sy Soafara

(Paysans pauvres au retour des travaux de champs, fatigués, rejoignant leur maison, ils semblent faire une pause. Ils montrent toujours la gaieté malgré la dureté de la vie)

Poor farmers coming back home from the fields, tired; they seem to pause. They always show cheerfulness in spite of the harshness of their life

NA ASA TSARA NA RATSY, NA MANAN-KARENA NA MAHANTRA DIA FAFINARETANA NY AMBANIVOHITRA NY OLONA REHETRA NY ASA, INDRINDRI' NY OLONA MALAGASY

Kirsten et Tsiry, classe de 4ème

(Que leur travail soit considéré comme bon ou mauvais, tous les gens qui habitent à la campagne, riches ou pauvres, et surtout les Malgaches, accomplissent leur tâche avec courage et bonne humeur)

(Whether their work is regarded as good or bad, rural people, rich or poor, and especially the Malagasy people, accomplish their work with courage and joy)

SARY TENA BE LOKO. AZO ADIKA FA NA MAHANTRA ARY IZY IREO DIA AFAKA MAMPISEHO FIFALIANA HATRANY.

Lalao, Ambalavao

(Photo riche en couleurs qui montre leur soif de vivre dans la joie malgré la pauvreté)

(Picture rich in colors which shows these farmers' love of life in their joy in spite of poverty)

MAHAVOKATRA BE ILAY TOERANA , HITA ANEFA FA MAHANTRA IHNAY NY OLONA FA AMPY SAKAFO.

Vero

(La photo montre une région fertile – bien que les gens soient en apparence pauvres, ils sont au moins bien nourris et en bonne santé)

(The picture shows a fertile area – although the people appear poor, they are at least well nourished and in good health)

LA VRAIE VIE : SANS CONTRAINTES, SANS STRESS, SANS VOITURE, SANS POLLUTION, SANS TECHNOLOGIE. JUSTE L'HOMME ET LA NATURE.

Harlys Kevin Rambeloson, classe de 4ème

(The true life: without constraints, stress, cars, pollution, technology. Just man and nature)

HITA SORITRA ENY AMIN' NY ENDRIK' IZY MIANAKA IRETO NY FITIAVANA HIASA TANY, ENY NA DIA KARAMA AZA SATRIA DIA TENA HITA HOE MAZOTO TOKOA IZY IREO ARY DIA TANA MITANA NY MAKA FOMBA MALAGASY AZY.

Rabekoto Serge, comptable

(Avec une simple angady, les deux campagnards accomplissent avec amour leur travail sans crainte et sans soucis. Ils gardent toujours le sourire selon la coutume malgache pour soutenir leur courage)

(With a simple angady, the two rural people accomplish their work with love but without fear or concern. They always keep a smile as it is a Malagasy habit to sustain their courage)

DES GENS CULTIVANT COMME LA MAJORITÉ DES CAMPAGNARDS MALGACHES : LA LIBERTÉ SANS CONFORMITÉ.

Johary Andry Rakotomalala, classe de 4ème

(People farming as the majority of the rural Malagasy do: freedom without conformity)

BONNE SITUATION, PAYSAGE PAISIBLE ET CALME, VIE NATURELLE. VIE SIMPLE MAIS SANS PASSE-TEMPS.

Antoinette Faniry Antonio, classe de 4ème

(Good situation, peaceful and calm landscape, natural life. A simple life but without pastime)

UNE EXPLOSION DE COULEURS À LA CAMPAGNE : LES PAYSANS, MÊME S'ILS TRAVAILLENT DUR LA TERRE, SONT HEUREUX DE LEUR CONDITION ET LÀ OÙ ILS SONT.

Oukaby Ashna, classe de 4ème

(An explosion of colors in the countryside: the peasants, even if they work hard in the fields, are happy with their condition and where they are)

Travelling Through Time - Voyage dans le Temps

Dans cette rubrique le journal invite des gens à nous parler de ceux qui ont marqué la Conservation et le Développement à Madagascar. Nous donnons ici la parole à Christian Camara, Missouri Botanical Garden, Madagascar pour qu'il nous parle de :

PROFESSEUR RABODO ANDRIANTSIFERANA

Lorsque l'ingénieur forestier Henri Andriantsiferana, se faisait accompagner de ses enfants lors de ses innombrables travaux d'inventaire de la flore forestière dans la région de Farafangana où il avait été affecté comme Chef de cantonnement, par le Service des Eaux et Forêts, il était bien à cent lieues de se douter que sa fille de 10 ans allait soutenir plus tard la toute première thèse de Doctorat d'État es sciences à Madagascar !

C'est au cours de ces travaux de terrain avec son père que la petite Rabodo apprit à aimer la nature, à découvrir les plaisirs simples du camping en plein forêt et à s'habituer aux longues marches par monts et par vaux et au cours desquelles pourtant, son rôle principal se résumait à indiquer les arbres qui possédaient les mêmes feuilles que celles que son père lui avait tendues plus tôt. Ce n'était pas toujours facile pour une fillette de son âge, mais elle s'y prêtait de bonne grâce car elle admirait beaucoup ce père si passionné de la nature, et en particulier de botanique.

Son caractère persévérant et perfectionniste, Rabodo l'a hérité de sa mère brodeuse et photographe. À la maison, lorsqu'elle se faisait aider par sa mère pour réviser ses leçons, celle-ci ne renonçait jamais, même après une crise de larmes, tant qu'elle n'arrivait pas encore à assimiler et à retenir toutes ses leçons. Grand bien lui en avait fait car au cours des années primaires et secondaires de sa scolarité, Rabodo a toujours été citée comme une élève exemplaire.

À l'École Supérieure des Sciences d'Antananarivo, où elle suivait les filières Médecine et Sciences Naturelles, elle devait se décider sur les deux choix qui s'offraient à elle à l'issue de l'année préparatoire : soit poursuivre les études en médecine soit se consacrer aux sciences naturelles. Elle s'imaginait mal passer sa vie à l'hôpital mais ne se sentait pas particulièrement attirée par la classification de la flore et de la faune non plus. Cette décision, elle n'arrivera jamais à la prendre complètement quand bien même elle opta pour poursuivre ses études à Montpellier, France, où elle obtint les diplômes des deux premiers cycles es Sciences Naturelles.

Malgré son succès universitaire à l'étranger, l'appel de la mère patrie se faisait de plus en plus sentir, et avec sa formation en botanique approfondie, elle se décida de retourner à Madagascar et d'y trouver un sujet pour sa thèse. Faute de poste disponible à la Faculté des Sciences, elle dut patienter à l'École Nationale de Médecine de Madagascar comme Monitrice pendant une année. Ensuite, elle commença sa carrière à la Faculté des Sciences, à l'Université de Madagascar, d'abord comme Assistante puis Maître Assistante et finalement Chef de service de Physiologie Animale. C'est ainsi qu'elle a pu trouver un sujet pour son Doctorat d'État : « Contribution à l'étude biologique d'un lémurien malgache : le Microcèbe (*Microcebus murinus* Millers, 1777) », brillamment soutenu en 1975. Pionnière dans son sujet de recherche, elle dut inventer une grande partie des matériels dont elle avait besoin pour ses études. De plus, étant un animal nocturne, ce lémurien impliquait de longues séances de suivi la nuit pendant plusieurs mois. Mais passionnée par sa recherche, elle n'abandonna pas pour autant son projet et finit par démontrer que ce Microcèbe est un primate qui peut hiberner.

Monitrice et Assistante du Dr Constantin à l'hôpital Girard et Robic à Antananarivo en 1964.

Avec ses connaissances en médecine et en sciences naturelles, elle reçut la proposition d'une équipe de chercheurs travaillant sur l'effet cicatrisant d'une plante. Habituée des laboratoires et du manque de moyen disponible, elle dut emprunter la technique utilisée par les géographes pour sa recherche, la planimétrie qui lui permit de mettre en évidence l'accélération de la cicatrisation des plaies chez des cobayes. Après des essais cliniques concluants, le produit a été lancé sur le marché sous le nom de Fanaférol et breveté en 1985.

Cette recherche marqua pour le Professeur Rabodo Andriantsiferana le point de départ d'une réelle passion pour les plantes médicinales, ce qui nous ramène à l'époque où elle devait faire le choix entre la médecine et les sciences naturelles. Effectivement, la même équipe de chercheurs lui proposa de nouveau de continuer et de promouvoir les recherches sur les plantes médicinales avec eux, notamment avec la création en 1976 du CNRP (Centre National des Recherches Pharmaceutiques). Ainsi, le destin l'a contraint à poursuivre dans les deux domaines de recherche, mais sous une seule forme. Dès lors, ses recherches devinrent beaucoup plus orientées vers les activités pharmacologiques des plantes médicinales, et tout naturellement, elle embrassa les médecine et pharmacopée traditionnelles de toutes les régions de Madagascar, se vit même embarquée dans une incursion dans le domaine législatif lorsqu'elle dut effectuer

des études pour l'élaboration des textes devant réglementer les plantes médicinales et le statut des tradipraticiens à Madagascar ou encore de la reconnaissance de la médecine traditionnelle dans le système de santé officiel.

Faire participer les femmes à la prise de décisions lors d'un atelier à Antanandava, Ambatondrazaka en 1999.

Ces différentes recherches lui ont valu plusieurs séjours et travaux dans les fins fonds de la brousse malgache, d'Est en Ouest et du Nord au Sud et toujours des situations aussi variées qu'inattendues ! Lors d'une de ces missions de terrain à Namoly, dans l'Andringitra, elle se souvient aller frapper à la porte d'une habitation traditionnelle dont l'âge pouvait être deviné par sa vétusté et y trouva un vieillard vivant seul. Loin d'être hostile, le vieil homme fut ravi de sa visite et malgré sa pauvreté apparente remercia Dieu de lui avoir envoyé de si loin cette personne pour lui rendre visite. Il en était tellement reconnaissant qu'il lui offrit un pot de miel : tout ce qui lui restait comme nourriture dans sa maison. Il était prêt à la partager avec joie malgré sa situation matérielle.

Persuadée que tout développement commence d'abord par le développement de l'Homme et de tous les hommes et les femmes, et pas uniquement sur le plan matériel, le Professeur Andriantsiferana ne se contentait pas uniquement de la recherche sur les plantes médicinales, mais contribuait également dans des activités de développement et de conservation de la biodiversité de divers projets. Elle mettait un point d'honneur à faire participer les membres de la communauté de base lors des différentes discussions et faisait toujours en sorte de pouvoir donner aussi la parole aux femmes.

Membre du Comité Consultatif Africain pour la Recherche en Santé, le Professeur Rabodo Andriantsiferana a porté haut la recherche sur les plantes médicinales à Madagascar car elle a été à l'origine de la nomination du CNRP comme Centre Collaborateur de l'OMS (Organisation Mondiale pour la Santé) en 1985. Auteur de plus d'une cinquantaine de publications, le Professeur Rabodo Andriantsiferana admet qu'elle n'a jamais été maîtresse de son destin. Elle concède que ce sont les événements qui l'ont toujours obligée à réagir, ce qui explique parfaitement les reconversions, les incursions dans d'autres domaines qui lui ont finalement apporté beaucoup de plaisir, permis d'établir des contacts aussi bien à Madagascar qu'à l'étranger, et élargi son horizon de la connaissance de l'Homme. Cependant, elle reconnaît également que son ingéniosité et sa détermination, des caractères que beaucoup de chercheurs malgaches doivent adopter à son avis, l'ont beaucoup aidée dans ses travaux de recherche.

Pratiquante, mais pas assidue selon ses propres termes, elle nous lance sans ambages : «Ma foi, je la vis !». Actuellement à la retraite, sans pour autant délaisser ses activités de recherche scientifique dans la lecture et l'enseignement, le Professeur Andriantsiferana se félicite d'avoir plus de temps pour s'adonner à d'autres activités moins scientifiques mais beaucoup plus artistiques : la broderie et la peinture. Qui a osé affirmer que les intellectuels sont mauvais pour les travaux manuels ?

CHRISTIAN CAMARA

40 ans d'histoire familiale rassemblés dans ce patchwork.

NÉCROLOGIE :
Charles Domergue nous a quitté le 31 décembre 2008. Quelle belle date ! À 23 heures. Quel panache, quel grand homme ! Cet homme qui a toujours imposé et défendu ses choix de vie a décidé de mourir à Madagascar en nous offrant une belle date anniversaire.

CORRIGENDUM

Corrigendum

Discovery of *Macrotarsomys bastardi* at Beza Mahafaly Special Reserve, southwest Madagascar

Youssouf Jack, I. A. and Rasoazanabary, E.

First published online: 10 December 2008

The first authors' surname appeared with a misspelling. The publishers would like to apologize to the authors and their readers for this error. The correct surname of the first author is stated below.
Youssouf Jacky, I. A.

IMPRESSUM

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