VOLUME 3 ISSUE 1 DECEMBER 2008

MADAGASCAR CONSERVATION & DEVELOPMENT

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

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MWC

Jane Goodall Institut Schweiz

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Image in Action

The attachment that we feel to Madagascar compels us to talk about it – its richness, its values, its people and about life lessons learned and taught. As these experiences may differ in many aspects, a journal is the ideal place for sharing our common ideas, as well as expressing our divergent thoughts and theories. It is also a conduit for the exchange and transmission of our ideas and perspectives to the world. Thus, it is the ambition of this journal to talk about Madagascar – it's natural richness and its conservation, about development and challenges in the country, and more generally about components and facets of conservation and development.

In this volume, the Journal launches two new rubrics, which emerged from the energetic enthusiasm of the authors, editors and our friends. Words are not the only way to formulate and share stories, pictures can carry messages as well; and they can speak without using words while still diligently evoking emotions and reactions in all of us. Now, we want to hear what your reactions are; we need to hear and to read how images from Madagascar capture and affect you. The Journal is doing this for the very first time and no matter who, whether men, women, or children, all of them have voiced their feelings about the photo of the little girl on the front cover of this volume.

We want you to participate in Voicing Over Pictures, to share your ideas, for those of you not having a scientific based project ready yet, or simply to tell your experience in a different way. For example, those who have the courage to circulate photos and stories about the dead stranded dolphins of the port of Antsohihy. They suspected a link between the sonar systems of Exxon Mobil and the dolphins' navigation off the coasts of Analalava and Antsohihy (and they may be right, as such correlations are scientifically proven in peer-reviewed publications) even though they did not want to believe that such a tragedy could happen in their Madagascar. These people felt motivated to reach out into the world and show us what is happening. Madagascar can sometimes seem too far away from the rest of the world but this story brings us back to our sense of place in the country. Some pictures have been circulated but lately there has been only a dull silence, as scientists take time to research the issue and publish the evidence that they find.

We have received a broad variety of contributions to this volume such as "Bats as bushmeat in Madagascar". This is not only the first MCD review focussing on Madagascar's bats, but it also shows some impressive pictures including a rather unusual and unfortunate shot of bats in a context that is more common than you think: the bat on the dinner plate. Another contribution addresses one of the top 25 most endangered primates in the world. Instead of resigning and continuing what others of their ilk have done for generations (and seriously risking a listing in the history books under the chapter 'Extinct') the White-collared brown lemur has adapted to new and changing situations and has even been flexible enough to tackle the aftermath of cyclones and start feeding on mushrooms and spicy invasive plants. Is this a recipe for survival? We shall see.

In another story, the authors of the Manambolomaty Lake Project draw on local taboos and beliefs to establish a conservation framework for the protection of natural resources – a success story showing how important the traditional knowledge and culture of the local people is to achieving conservation that really matters.

Sharing information is important, that is nothing new. Before you can share, however, you need the ability to access it. In a piece about the power of radio, the authors show that radio broadcasting can be utilized beyond the daily spread of news and entertainment: it can also be an effective tool for community outreach. This has so far been 'off the radar' for most international aid agencies. Broadcasting information and knowledge over the radio can be an effective tool in the fight to alleviate poverty; which is so far still the biggest challenge in Madagascar.

As our words mark the passage of time into history, then you will be part of Madagascar's history of tomorrow. MCD is presenting another new rubric; Travelling Through Time will be talking about people who have written Madagascar's history in the past century, about people who were building on Madagascar's milestones for present and future conservation and development endeavours.

There are people who have been participating in Madagascar's history. Some of them are almost living legends; they have made their imprints on this island; and whether they are appreciated or not, people talk about these personalities. At the beginning of the 19th century oil mining industries (often with governments in the background) were endorsing renowned geologists for their endeavours such as Raymond Decary (1891-1973) who over the years became an accomplished humanist and naturalist. There is also the story of Charles A. Domergue, a hydro-geologist who also ended up dedicating his life to development in southern Madagascar where he pursued scientific studies and the conservation of the biological riches of Madagascar that mesmerized him. We invite you to talk in Travelling Through Time about your own heroes, men and women who have been the pioneers and advocates for Madagascar's Conservation and Development.

Returning to the picture as a medium of information, some of these are also meant to satisfy the classic clichés, the ones that reinforce stereotypes that the rest of the world has about Madagascar. Madagascar is a country of the South, and the world expects to see pictures mirroring these characteristics. In the South, mining is often married with the traditional picture of gold miners: deep pits bored by using the *angady* (the Malagasy spade), causing sweaty and muddy foreheads on the miners' emotionless faces while the mining dumps grow bigger and taller. One might think of a new Germinal or Assommoir-like novel of Emily RaZola's, with the *toka Gasy* replacing the absinthe, with the North pointing fingers and watching the South. However, the question remains, what is the real picture? Modern mines are equipped with sophisticated exploitation tools, and the companies have the backing of conduits of social and environmental impact studies, employing an international guild of workers, efficient and trained in using the latest technology, rearing to go. The Journal would like to call upon people who know about these mining activities and who are studying specific social, economic and environmental impacts; people who also are aware that these activities are unavoidable, and people who know that tropical forests are disappearing quickly from the maps of Madagascar, and with them the Indris that sing no longer, crying if they only could. We need these people to tell their stories and share their expertise and experience, since we all want to know and would like to understand what the benefits and negative impacts of large-scale mining or farming are for Madagascar.

The Journal would like to emphasize one more time that sharing information between agencies (governmental and non), universities and private persons is crucial. Whether you are in the field, in a forest, a community or a laboratory; sharing and informing is the most important step to moving Madagascar further ahead! You can simply share your impressions of the breath-taking photo on this volume's cover (which has been kindly contributed by Peter Oxford and Reneé Bish); as college students, children and older people have done, or you can go further and contribute more to the information sharing in the pages of this Journal. Submit us your stories and impressions as photo essays, or bring your experiences and findings to paper and send us articles, reviews or essays.

We are sure you will enjoy the articles in this issue and we hope to see more in the near future.

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

Image en Action

Comme tous ceux qui sont affectivement attachés à Madagascar, nous aimons parler de cette grande île, de ses richesses, de ses valeurs profondes, de ses gens, des leçons de vie qu'ils nous ont inculquées, mais si nos expériences aux uns et aux autres ont Madagascar en commun, elles diffèrent certainement en tous points et un journal est ainsi le lieu idéal pour échanger nos points de vue. Ici nous voulons parler des richesses naturelles de Madagascar et de leur protection, de développement et des défis à relever, ou un seul aspect lié à la protection de la nature ou au développement mais surtout et avant tout, nous invitons des hommes et des femmes à prendre la parole.

Le journal lance ainsi deux nouvelles rubriques qui sont nées de l'enthousiasme des auteurs, des éditeurs et de nos amis qui partagent tous cette même volonté de communiquer; les mots sont loin d'être les seuls outils de communication et si nous ne pouvons employer tous les moyens ici, nous savons cependant que les images véhiculent bien des messages, ont cet incroyable pouvoir de nous émouvoir et nous parlent. Et nous avons besoin de vous, de vous entendre, de vous lire, comme nous l'avons fait ici lorsque nous avons donné la parole à des femmes, des hommes et des enfants pour qu'ils nous disent avec leurs mots, leur sensibilité, ce qu'ils ont entendu dans les yeux de cette enfant.

Et nous vous attendons pour participer à cette rubrique 'Voicing Over Pictures' *ou 'Paroles d'Images' pour partager vos idées, pour communiquer en attendant d'avoir matière à produire un article scientifique, ou pour le dire autrement. Nous pensons par exemple à ceux d'entre vous qui ont eu le courage de faire circuler ces photos de dauphins échoués dans le port d'Antsohihy. Certains ont soupçonné un rapport entre*

les sonars à balayage latéral d'Exxon Mobil et l'échouage des dauphins sur les côtes proches d'Analalava et d'Antsohihy, ils ne peuvent pas avoir tort car tout cela est connu depuis bien longtemps ; de tels faits sont scientifiquement prouvés et publiés dans des revues à comité de lecture, mais ceux qui constataient les faits sur les côtes malgaches ne voulaient tout simplement pas croire que cela se passait aussi chez eux, en étaient émus, voulaient le hurler, et très fort car Madagascar est parfois tellement loin du reste du monde ! Quelques photographies circulèrent mais furent rapidement remplacées par un silence pesant car la science a besoin de bien plus d'éléments et qu'il lui faut du temps pour procéder aux recherches et mettre ses résultats sous presse.

Nous avons reçu des contributions variées pour ce volume et pour n'en citer que quelques unes, l'article « Bats as bushmeat in Madagascar *» est une première sur les chauves-souris pour le journal mais qui nous montre des images impressionnantes de ces animaux dans un contexte qui n'est pourtant pas inhabituel, celui où ils se retrouvent accommodés dans une assiette.*

Un autre article concerne l'un des 25 primates les plus menacés du Monde. Et plutôt que de démissionner et de poursuivre comme d'autres de la lignée l'avaient fait pendant des générations (pour prendre inéluctablement le risque d'aller rejoindre les livres d'Histoire sous la rubrique 'Éteints'), le Lémurien à collier blanc montre qu'il s'adapte à une situation changeante en étant capable de composer dans une forêt ravagée par un cyclone et de s'alimenter de champignons et de fruits épicés d'espèces allogènes ; recette pour survivre ou non, il s'agit pour le moment d'une affaire à suivre.

Les auteurs de l'article sur le projet du lac Manambolomaty s'inspirent des croyances et des tabous locaux pour mettre en place un réseau destiné à la protection des ressources naturelles – l'histoire d'une réussite qui relate une fois de plus à quel point les gens sont importants pour protéger une nature qui compte.

Partager l'information est primordial et ceci n'est pas un scoop ! Mais avant de pouvoir partager il vous faut les moyens de le faire comme il est montré ici dans l'article sur la radiodiffusion qui peut aller au-delà de la transmission de nouvelles et de divertissement en constituant un outil capable de s'adresser aux communautés les plus isolées et qui étaient loin de toutes les priorités des agences d'aide internationales. La radio peut constituer un outil de choix pour lutter contre la pauvreté qui reste encore et par-dessus tout le plus grand défi à relever à Madagascar.

Ainsi, les mots marqueraient-ils le passage du temps dans l'Histoire, de sorte que vous êtes alors tous la future Histoire de Madagascar. Dans ce contexte, le journal présente donc une autre rubrique pour parler des gens qui ont écrit l'histoire du siècle dernier de Madagascar, de ceux qui ont posé des jalons sur la route de la conservation et du développement présents et futurs de l'île.

Car il y a des gens qui ont participé à cette Histoire, parfois des légendes vivantes qui ont marqué l'île de leur empreinte, on les aime ou non mais on parle d'eux. Au début du XIXe siècle, les explorations pétrolières firent appel à d'éminents géologues et nous nous rappelons de Raymond Decary (1891-1973) qui est, par la suite, devenu un humaniste et un naturaliste chevronné. Plus jeune, un autre géologue a partagé un destin semblable en consacrant sa vie au développement du Sud de Madagascar ainsi qu'à la science et la protection de ses richesses naturelles, ce naturaliste est Charles A. Domergue. Dans Travelling Through Time *ou Voyage dans le Temps, nous donnons la parole à ceux qui veulent nous parler de leurs héros, de ces hommes et ces femmes qui ont marqué l'histoire de la protection de la nature et du développement de Madagascar.*

Pour revenir aux paroles émanant des images, il nous faut admettre que certaines d'entres elles sont aussi destinées à contenter les clichés, ces caricatures qui rassurent et qui doivent traduire la bonne marche du monde. Madagascar est un pays du Sud et le monde veut y voir des images du Sud. Dans le Sud, l'exploitation minière se marie avec l'orpaillage traditionnel, des puits profonds creusés à la sueur du front, des terrils érigés à la force des angady (les pelles locales) dans une ambiance où on frôle un nouveau 'Germinal' ou 'Assommoir' d'un Émile RaZola où le toka gasy (rhum local) remplacerait l'absinthe dans le Sud qui sera pointé du doigt par le Nord. Mais savons-nous seulement à quoi ressemble la réalité ? L'exploitation minière moderne met en place des chantiers élaborés, des moyens d'extraction sophistiqués, se contraint à réaliser les études sociales et d'impact environnemental conformément à des normes internationales, fait appel à des travailleurs et experts de toutes nationalités, efficaces et rompus à utiliser les dernières technologies en la matière. Le Journal voudrait donc inviter ceux qui connaissent ces activités minières, qui étudient spécifiquement les impacts sociaux, économiques et environnementaux mais aussi tous ceux qui admettent qu'il n'y a généralement pas le choix, qui savent que des forêts tropicales disparaissent rapidement de la carte de Madagascar, et avec elles des Indris qui ne chantent plus mais pleureraient s'ils le pouvaient ou si nous pouvions les entendre. Nous avons besoin de vous entendre avec des mots, des paroles d'images et vous invitons à partager vos expertises et expériences car nous voulons tous savoir et nous voudrions comprendre ce que sont les avantages et les inconvénients des exploitations minières ou agricoles à grande échelle à Madagascar.

Madagascar Conservation & Development voudrait insister une fois de plus sur le besoin de partager les informations, aussi bien celles des agences gouvernementales que non gouvernementales, des universités ou des particuliers, que des gens de terrain, qu'ils soient en forêt, dans un village ou dans un laboratoire ; le partage et l'information sont des éléments déterminants pour faire avancer Madagascar ! Vous pouvez simplement partager votre sensibilité en nous disant ce que vous voyez dans des images comme l'ont fait des collégiens, des enfants et des moins jeunes pour la superbe photo de couverture aimablement mise à disposition par Peter Oxford et Reneé Bish. Mais avant tout, le journal voudrait inviter des gens qui travaillent dans la Conservation et le Développement à participer à l'échange de l'information ! Soumettez nous vos histoires et vos impressions, sous la forme d'images accompagnées d'une courte légende, ou partagez vos expériences et vos découvertes dans des articles, des revues ou des essais.

Nous sommes certains que vous apprécierez la lecture de ce numéro et espérons vous y voir davantage dans un proche avenir.

Lucienne Wilmé, Rédacteur en chef

Patrick O. Waeber, Rédacteur Fondateur


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PRÉFACE

Un Arbre ne fait pas la Forêt

En tant que Malgaches, nous apprécions la beauté de notre patrimoine naturel et la richesse de notre culture. Ces éléments contribuent à modeler le sens collectif de l'identité et de la fierté nationales à Madagascar. Bien que de divers horizons culturels et géographiques, le peuple malgache se sent uni par ces éléments qui, en même temps, mettent en exergue la diversité du pays. Les Malgaches partagent ces richesses entre eux et invitent les autres à les connaître, à les apprécier et à les respecter. Avec le nouveau Systèmes des Aires Protégées de Madagascar, nous célébrons cet héritage naturel à travers les six catégories d'aires protégées préconisées par l'UICN : les Réserve naturelles intégrales, les Parcs nationaux, les monuments naturels, les Aires aménagées pour l'habitat et les espèces, les Paysages terrestres ou marins protégés et les Aires protégées de ressources naturelles aménagées. Ces symboles nationaux contribuent à notre identité malgache de plusieurs façons. Ils dépeignent une diversité de cultures et d'environnements naturels. Ceux-ci peuvent être situés dans n'importe quelle région du pays, au Nord comme au Sud, à l'Est comme à l'Ouest. Ce sont des liens tangibles non seulement avec le passé et le présent mais aussi avec le futur. Ces endroits patrimoniaux nous ouvrent une fenêtre sur le monde et mettent en évidence notre devoir d'assurer de façon continue, la protection et la mise en valeur d'un patrimoine dont l'importance dépasse nos frontières.

En effet, nous assistons à l'heure actuelle, à un foisonnement de projets, nationaux et internationaux, de recherche générant ainsi des données considérables et nous ne pouvons que nous en féliciter. Il suffit de consulter les excellents articles, qui traitent de la culture, de la biodiversité et du développement du peuple Malgache, publiés dans le présent numéro du bulletin de MCD, ainsi que dans les précédents, pour s'en convaincre. Ces données nous sont utiles pour honorer notre devoir envers la conservation de ce patrimoine naturel, ce qui nous permettra de transmettre à la génération suivante un patrimoine intact, plus ou moins !

Mais, comme nous le savons tous, la nature est encore loin d'avoir livré tous ses secrets. Ce qui m'amène à dire que la recherche ne doit plus être l'apanage des chercheurs uniquement ! Encore mieux, la compréhension de son importance doit dépasser les cercles de la communauté scientifique, des responsables de la gestion des ressources naturelles et des responsables politiques, et intéresser tout un peuple car, finalement, les résultats de ces recherches visent à promouvoir son développement harmonieux dans son propre environnement naturel et culturel. Ainsi, quelle que soit la modestie de nos connaissances, quels que soient nos manques en ressources et quels que soient nos retards sur la technologie, nous avons tous le devoir d'apporter à la recherche notre contribution.

FOREWORD

A Tree does not make a Forest

As Malagasy, we appreciate the beauty of our natural patrimony and the richness of our culture. These elements contribute to the collective sense of national identity and pride in Madagascar. Despite having different cultural and geographical horizons, the Malagasy people feel united through these elements, which at the same time stress the diversity of the country. The Malagasy share this richness amongst each other and invite others to experience it, to appreciate it and to respect it. With the new system of protected areas of Madagascar, we celebrate this natural heritage throughout all of the six categories of protected areas recognised by the IUCN: the strict nature reserves, the national parks, the natural monuments, the areas established for habitat and species, the protected terrestrial or marine areas and the protected areas for the conservation of natural resources. These national symbols contribute in different ways to our identity. They depict a diversity of culture and natural landscapes. These can be located at any region of the country, north or south, east or west. They are tangible links not only to the past and the present but also to the future. These sites, our patrimony, open a window to the world for us and underline our duty to reassure in continuous fashion, the protection and development of a heritage whose importance goes beyond our boundaries.

Now, we Malagasy are involved more than ever before on a multitude of research projects, both national and international, generating considerable data and we can only congratulate ourselves for that. It suffices to consult the excellent articles on culture, biodiversity and the development included in this present issue of the journal MCD, as well as in the previous ones, for a concrete demonstration of our active participation in research. This data is useful for us to honour our duty towards the conversation of this natural heritage, guiding us as to how best to pass our natural legacy to the next generation.

But, as we all know, nature is far from having revealed all its secrets. Research activities need to be encouraged yet further, and the fruits of this research must spread far beyond the confines of the scientific community to those responsible for the management of natural resources, to politicians, and out into the realms of the whole nation. This information is needed by all concerned with the harmonious development of their natural and cultural environment. So despite our modest knowledge, our lack of resources and our technical inadequacies, we all have the duty to encourage research and be ready to integrate its results into our decision-making.

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Taboos and social contracts: Tools for ecosystem management – lessons from the Manambolomaty Lakes RAMSAR site, western Madagascar

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ABSTRACT

Traditional taboos and social contracts played an important role in managing the Manambolomaty RAMSAR site. Taboos are defined as a prohibition imposed by social custom as a protective measure' and social contracts are – in conservation sense – a common agreement for achieving conservation, sustainable development and development of resources objectives. The Manambolomaty Lakes RAMSAR site, District of Antsalova in western Madagascar, is composed of four lakes (Soamalipo, Befotaka, Ankerika and Antsamaka) surrounded by the Tsimembo deciduous forest. The first three lakes with forest surrounding encompass 14,701 ha and are being managed by two local Associations: FIZAMI (*FIkambanana Zanatany Andranobe MIray*) and FIFAMA (*FIkambanana FAmpandrosoana Mamokatra Ankerika*). The associations have used traditional taboos and social conventions to manage their local natural resources by incorporating a GELOSE (*GEstion Locale SEcurisée*) management system to conserve biological diversity, maintain resource sustainability and socio-economic viability. This site has the highest concentration of the endemic and critically endangered Madagascar fish eagle (*Haliaeetus vociferoides)*, representing 10 % of the global population, and many other species of different faunal groups are also in good conservation status such as Decken's sifaka (*Propithecus deckeni*) and Western lesser bamboo lemurs (*Hapalemur occidentalis*) and Madagascar flying fox (*Pteropus rufus*). Culturally, the site is known as a unique source of the endemic tree *Hazomalania voyroni* (Hernandiaceae), which is used by the *Sakalava* people for constructing coffins, and being buried in a coffin made of this wood is a great honour for the *Sakalava* people. From Manambolomaty's Lakes fish yields, estimated at 60-100 tons per fishing season, FIZAMI and FIFAMA are one of the few Malagasy Associations with active bank accounts supported by management of their natural resources and associated activities. Their fisheries management system has increased the annual local revenue estimated at more than $ 1,562 US / fisherman per season. The tax of fish sales to wholesale fish buyers forms 56 % of the two local Commune's budgets. This has made the Community-Based Wetlands Conservation at the Manambolomaty Lakes site well known in the conservation circles within Madagascar and has been modelled by other organizations and associations. Consequently, the Manambolomaty Lakes site is in the process of being added into the System of Protected Areas of Madagascar (SAPM) (Figure 1).

RÉSUMÉ

Les tabous traditionnels et conventions sociales jouent un rôle important dans la gestion du site RAMSAR Manambolomaty. Le tabou peut-être défini comme une prohibition imposée par la coutume sociale à titre de mesure de protection tandis qu'en terme de conservation, le contrat social est un accord commun pour atteindre les objectifs de conservation, de développement pérenne ainsi que du développement des ressources. Le site RAMSAR Manambolomaty, situé dans la partie occidentale de Madagascar, district d'Antsalova, est composé de quatre lacs (Soamalipo, Befotaka, Ankerika et Antsamaka) dont les trois premiers ainsi qu'une partie de la forêt caducifoliée de Tsimembo – totalisant environ 14,701 ha – sont gérés par deux Associations locales : FIZAMI (*FIkambanana Zanatany Andranobe MIray*) et FIFAMA (*FIkambanana FAmpandrosoana Mamokatra Ankerika*). La gestion des ressources naturelles par ces deux Associations se base sur le respect des tabous traditionnels et conventions sociales. FIZAMI et FIFAMA ont adopté le système de gestion du type GELOSE (*GEstion LOcale SEcurisée*) pour conserver la diversité biologique et assurer les activités socio-économiquement durables. Ce site abrite la plus forte concentration d'une espèce d'oiseau gravement menacée, le Pygargue de Madagascar (*Haliaeetus vociferoides)* représentant 10 % de la population globale ; plusieurs autres espèces fauniques telles que le Propithèque de Decken (*Propithecus deckeni*), l'Hapalémur occidental (*Hapalemur occidentalis*) et la Roussette (*Pteropus rufus)* y bénéficient aussi d'un bon statut de conservation. Sur le plan culturel, ce site abrite une ressource unique de l'arbre endémique *Hazomalania voyronii* (Hernandiaceae), une espèce utilisée par la tribu *Sakalava* dans la confection de cercueils car il n'est de plus grand honneur pour les *Sakalava* que de pouvoir se faire enterrer dans un cercueil confectionné dans cet arbre. Le produit de la pêche à Manambolomaty est estimé à 60-100 tonnes par saison et à l'issue de la gestion des ressources naturelles et des activités y afférentes, FIZAMI et FIFAMA sont

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parmi les rares Associations malgaches qui ont réussi à avoir un compte bancaire. Leur gestion de la pêcherie augmente considérablement le revenu annuel local qui est estimé à plus de 1 562 US$/pêcheur par saison. La taxe collectée à partir de la ristourne de pêche constitue près de 56 % du budget communal des deux communes. Cette gestion communautaire de la zone humide de Manambolomaty est si bien connue dans le domaine de la conservation à Madagascar, qu'elle sert de modèle pour d'autres organisations et associations. En conséquence, le Complexe Lacustre Manambolomaty est proposé pour être inclus dans le Système des Aires Protégées de Madagascar connu sous le sigle SAPM.

KEYWORDS: Manambolomaty Lakes, RAMSAR, Community-Based Wetland Conservation, Taboo, GELOSE, SAPM, western Madagascar, Antsalova.

INTRODUCTION

Biological conservation and ecosystem management require strong involvement of local human communities and self-enforced codes of conduct such as social conventions, traditional taboos and religions. The broad definition of a taboo is 'a prohibition or ban imposed by social custom or as protective measure' (Webster 1993). In conservation, social contracts can be defined as an adequate system of management that is established by communities with goals of conservation, sustainable development, and development of resources (Watson et al. 2007). Taboos and social contracts play a key role in the achievement of management objectives (McDonnell and Pickett 1993, Lubchenco 1998, Colding and Folke 2001), and North (1990, 1994) defined these behavioral norms as "Informal Institutions". Most of the world's conservation hotspots are associated with regions where traditional societies occur (Myers et al. 2000, Orme et al. 2005). Informal institutions have been neglected in conservation planning in biodiversity rich developing countries (Alcorn 1995, Robbins 1998). Habitat protection through the creation of reserves has been the major approach for protecting biodiversity (McNeely 1993, Gadgil 1998). Reserve creation has often overlooked the behavioral norms (Lingard et al. 2003). Recently, it is believed that transformation of these informal institutions for the purpose of conservation and sustainable management of resources, and species and natural heritage conservation may reduce considerably the current high cost of formal institution enforcement (Colding and Folke 2001, Lingard et al. 2003). Consequently, this has lead to the concept of Community-Based Natural Resources Management which is based on strengthening social conventional rules and norms (Child 1996).

We have seven years (2001-2008) of experience in assisting and directing two local Associations, FIZAMI (*Fikambanana Zanatany Andranobe Miray*) and FIFAMA (*Fikambanana Fampandrosoana Mamokatra Ankerika*), in their government-authorized management and sustainable use of natural resources and in Community-Based Wetlands Conservation in western Madagascar. The conservation role of these two associations is based on the Traditional Ecological Knowledge (TEK) concept that represents multiple bodies of knowledge accumulated through many generations of close interactions between people and the natural world (Drew 2005), traditional taboos and social conventions (Berkes et al. 2000, Colding and Folke 2001). In this paper, we discuss how taboos and social conventions related to Manambolomaty wetland management have successfully contributed to the local fisheries activities, wetlands and forest resource management and conservation of the critically endangered Madagascar fish eagle (*Haliaeetus vociferoides*). As

FIGURE 1. The Manambolomaty Lakes site is in the process of being added into the System of Protected Areas of Madagascar.

these informal institutions are site-specific (Colding and Folke 2001, Drew 2005), the 'Lake Keeper (*Tompondrano*)' – through several generations – constitutes in the Manambolomaty Lakes site an important source of information for taboos and TEK that were used to establish the Associations' charters (*Cahier des charges*) and the RAMSAR management plan in establishing the community conventions and traditional taboos regarding wetland and forest resource use.

METHODS

The Associations' charters and RAMSAR management plan were reviewed to get data on taboos and social conventions regarding wetland and forest resource use. 'Ancestral spirits' spoke also on behalf of the *Tompondrano* and his family to remind publicly – especially during the opening fishing season ceremony – the main traditional taboos. Following the current generic method for community-based fishery management (Molares and Freire 2003), annual regulation of fishermen, fish yields and fishing period were recorded to assess the impact of fishing activities on fish populations. Fishermen numbers were obtained and displayed on their dugout canoes by permits for each fisherman prior to the opening fishing season. Daily fish catches by each fisherman – that are composed mostly of introduced *Tilapia* spp. (Watson et al 2007) – were recorded and weighted by a designated fishing camp leader during the fishing season. For the respect of tradition, the opening fishing season was set in June, a period believed by *Sakalava* people as a good month and called locally as *Volambita*. During the fishing season, net length and mesh size of each fisherman were monitored by FIZAMI and FIFAMA in collaboration with Antsalova Forestry Representatives and The Peregrine Fund for technical assistance. Also, fishing camps and forest resource use were periodically checked for fish salting, slash-and-burn agriculture or forest burning and clandestine camps. At each camp, fuel wood utilized by fishermen for drying fish were checked to see if fishermen were cutting live trees. To asses the impact of wetland and forest resource use on Madagascar fish eagles – as it is a flagship and umbrella species, its conservation helps to protect many other threatened taxa and wetland ecosystem as whole – each occupied nest was visited three times during the breeding season, during eggs laying, hatchling and dispersal periods, and to follow the population status (for more details see Rabarisoa et al. 1997, Watson et al. 2007).

MANAMBOLOMATY LAKES COMPLEX – HISTORICAL OVERVIEW The Community-based Conservation and Madagascar fish eagle (*Haliaeetus vociferoides*) project activities were carried out within the Manambolomaty Lakes (S19°01'11"; E44°26'08"; Figure 2), one of the first RAMSAR sites designated in Madagascar along with Tsimanampetsotsa Lake on 25 September 1998. This site is in central western Madagascar and includes four major lakes (Soamalipo, Befotaka, Ankerika and Antsamaka) and they are surrounded by the Tsimembo deciduous forest. The *Sakalava* tribe is the major ethnic group in this area (TPF and DWCT 2003). This study was conducted at Soamalipo and Befotaka Lakes in the Masoarivo Commune and managed by the FIZAMI Association while Ankerika Lake resides in the Trangahy Commune and it is managed by the FIFAMA Association. Together the two Associations manage an area of lakes and forest of approximately 14,701 ha and the two Communes represented the nearest local authorities that are in charge of supervision and management directive for both Associations.

In terms of biodiversity, more than 50 species of water birds have been documented (Razafimanjato et al. 2007), of which more than 20 species are endemic including at least five threatened species: Madagascar fish eagle (*Haliaeetus vociferoides*, CR), Madagascar teal (*Anas bernieri*, EN), Humblot's heron (*Ardea humbloti*, EN), Malagasy squacco heron (*Ardeola idae*, EN) and Madagascar plover (*Charadrius thoracicus*, VU). Additionally, 80 bird species have been recorded in the Tsimembo Forest of which 31 are endemic. Seven species of lemurs have been documented, of which two are threatened (Mittermeier et al. 2006): Western lesser bamboo lemur (*Hapalemur occidentalis*, VU) and Decken's sifaka (*Propithecus deckeni*, VU). This site is also the population stronghold for the endangered freshwater big-headed turtle (*Erymnochelys madagascariensis,* EN). Culturally, the Tsimembo Forest is the only known source of the endemic tree *Hazomalania voyroni* (Hernandiaceae) which is used by the *Sakalava* people for constructing coffins, and being buried in a coffin made of this wood is a great honor for the *Sakalava* people (Schatz 2000).

The two local Associations FIZAMI and FIFAMA were respectively created in November 1997 and January 2000 to protect wetlands, the biological diversity and local culture while regulating natural resource-related activities by means of enhancing traditional taboo and social conventions. This corresponds to the decentralization of natural resource management by encouraging local communities to manage their own natural resources under a 'management charter' following a governmental protocol, also known as GEstion LOcale SEcurisée (GELOSE) in accordance with Malagasy Law #96-025. A 3-year probationary management contract for both Associations was officially inaugurated on September 29th, 2001. The Associations' management charters' contain all social conventions and traditional taboos associated with the Manambolomaty Wetlands site. Traditionally, these wetlands are owned and controlled by the inherited *Tompondranos* (keepers of the lakes) who have ancestral powers of wetland management. In Soamalipo and Befotaka Lakes, the *Tompondrano* is the descendant of the *Sakalava* clan *Satria* and in Ankerika Lake this person comes from the *Tsialofo* clan. Originally, these clans used the Manambolomaty Lakes area for raising zebu cattle; their activities have had little impact on the integrity of the wetlands. During the 1990s there was a massive arrival of migrants who were unaware of wetland traditional taboos and rules which led to overexploitation of wetland and forests resources (TPF and DWCT 2003). Therefore, re-enhancement of traditional taboos via the establishment of social conventions (as written in Associations Charter) and the RAMSAR management plan were believed to be the best solution for maintaining the wetland and forest ecosystems.

RESULTS

SOCIAL CONVENTIONS, TRADITIONAL TABOOS AND WETLANDS FISHERIES MANAGEMENT From the Associations' Management Charters (*Cahier des Charges*) and RAMSAR Management Plan review, all of the outstanding traditional taboos and social conventions that correspond to wetland management objectives are listed in Table 1.

Apart from these written traditional taboos and social conventions, *Satria* and *Tsialofo* ancestors reminded on behalf

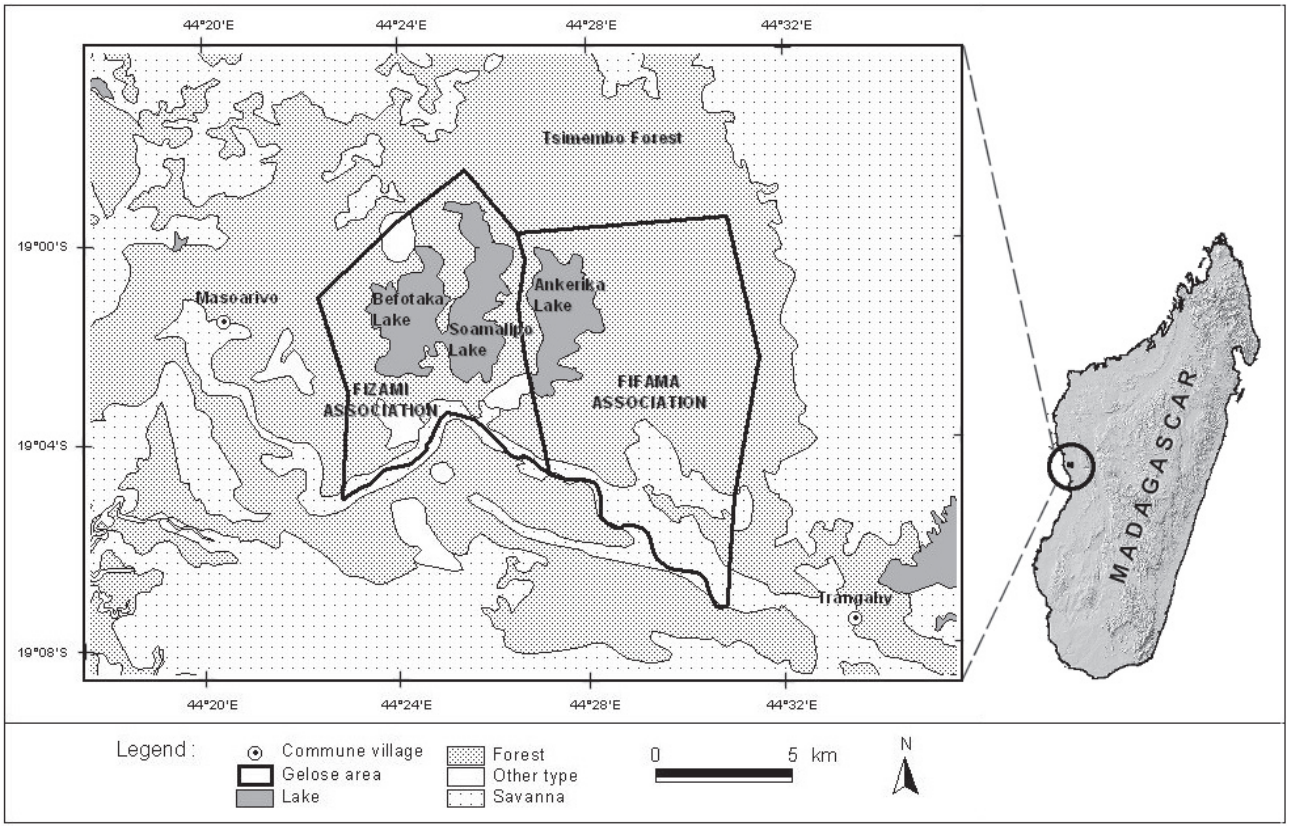

FIGURE 2. Map of Manambolomaty Lakes showing GELOSE resource management delimitation for FIZAMI and FIFAMA Associations in western Madagascar.

of the *Tompondranos* the main taboos regarding the use of lakes during the day of the opening fishing season.

The night prior to the official opening fishing season, local communities were overnighting under the one tamarind tree (*Tamarindus indica* Fabaceae) at the sacred site along the lakeshore. This tree has high spiritual value for *Sakalava* tribe. All night, they were singing traditional songs instrumented with traditional drums to excite the ancestors to attend and honor the opening fishing season ceremony the following day. This procedure continued until the ceremony was over about 13 hours later. The actual opening season begins in morning from 1000h-1100h. It is believed by the *Sakalava* people that this mid-morning time is the best period for the ancestral blessing. One sub-adult female of back-colored *Tompondrano's* zebu – with a white spot (about hand-size) in its front side and white tipped tail – was sacrified for expressing obedience towards the ancestors. The zebu's blood was drunken by ancestral spirit staying in *Tompondrano* family to express the continuity of life between today's generation and their ancestors. The meat taken from zebu's hump, heart, offal, and a black banana (rare variety of banana in the area) – that are considered as valuable food – were cooked without salt as a gift to the ancestors. *Sakalava* people believed that salt brought the bad luck into their life. These foods and drinks composed of honey (symbolizes a high respect toward the ancestors) and water were then dropped from a dugout canoe into specific corners of the lakes (three for Soamalipo / Befotaka and one for Ankerika) for the ancestors. Normally, ancestral servers included men and women wearing *lambahoany* (Malagasy cotton sheets) and women had their hair pleated in the *Sakalava* style. Once these groups of servers returned to festivity place, several groups of fishermen began fishing to mark the start time of the fishing season. Ancestral satisfaction was reflected by the number of persons within the *Tompondrano* family where the spirits of ancestors entered into them during the ceremony. Notably, these persons with ancestral spirit behaved differently than during their daily routine behaviors. The captured fish from these first groups of fishermen and the remaining zebu meat were shared among the community to receive benediction from the ancestors – and this marked the end of ceremony. All *Tompondrano* expenses for the opening fishing season ceremony were reimbursed from the sell of fishing permits at the end of fishing season.

CONSERVATION IMPLICATIONS Fishermen and fishing yields. The annual regulations of fishermen, fish yields, and the fishing season in the Manambolomaty Lakes have been recorded from 2002 to 2007 (Table 2). The number of fishermen working in the Manambolomaty Lakes has never exceeded the annual conventional quota of 400 persons. The annual fishing season opens in June for FIZAMI and most recently – in August 2005 and August 2006 – for FIFAMA when the *Tompondrano* (keeper of the lake) passed away during January 2005. From 2002 to 2004, fish yields were stable at 89-116 tons, and then they dropped to 34 tons in 2005. The long time spent for the process of *Tompondrano* replacement affected the FIFAMA Association functioning during this later year. In 2006 they increased to 67 tons and by 2007 were up to 200 tons.

FISH AND TREE HARVESTING METHODS None of the fishermen who are using the conventional net size (100 m x 1 m) and mesh width of three fingers are using salt to preserve fish. Annual average of 1-5 poachers were caught using long

TABLE 1. List of social conventions and taboos adopted by FIZAMI and FIFAMA Associations for the Manambolomaty Lakes wetland management

Wetlands Management objectives	Institutions	Description
Regulate resource use and extraction	Convention	Annually, a total of 400 fishermen from both Associations are allowed to fish (250 fishermen from FIZAMI and 150 from FIFAMA). Migrants have no right to fish, but they are allowed to buy and collect dried fish provided they have collecting licenses issued from Madagascar's National Fishery Department.
Regulate access to resources in time	Taboo	Annual fishing period is limited from June (coincides with *Volambita* in Malagasy moon calendar) to the end of November. The date of opening the fishing season depends exclusively on the *Tompondrano*'s decision.
Regulate resource withdrawal methods	Convention	Fishing nets of 100 m in length and with 3-finger sized mesh (6 cm) are to be used during the fishing season. During the closed season, local communities can fish, but they must use only fishing lines to catch fish for family consumtion.
	Taboo and Convention	The practice of salting fish is traditionally a taboo. With this practice, fishermen usually use extremely long nets with small mesh.
	Convention	Live plants can not be used as firewood.
Protect wetlands species in time and space	Convention	No wild animals can be harvested / hunted in the lakes apart from fish and Bush pigs (*Potamochoerus larvatus*) and Common tenrec (*Tenrec ecaudatus*) in the forest. Specific emphasis is given to threatened birds species such as the endangered Madagascar fish eagles, Meller's duck *Anas melleri* and Madagascar crested ibis *Lophotibis cristata*; as well as the endangered Madagascar big-headed turtle *Erymnochelys madagascariensis* (TPF and DWCT 2003). All lemur species are banned from hunting. Concerning tree species, emphasis is given to those species that have commercial value (e.g. *Dalbergia* sp.) or cultural (e.g. *Hazomalania voyroni*).
Regulate withdrawal of vulnerable life history stages of species	Convention	Common tenrecs that are pregnant or with young are prohibited to be hunted. In contrast, the introduced and destructive Bush pig can be hunted during all life stages throughout the year.
Preserve wetland integrity and beauty for future generations	Convention	It is prohibited to exploit or practicing slash-and-burn agriculture within the forest managed by the Associations.
	Convention	Fishermen camps are limited to eight specific sites authorized by the Associations to minimize their impact and disturbance on the wetland ecosystems.
	Convention	Burning forest habitat for any reasons is banned.
	Taboo	Transporting live charcoal embers on the water, relieving ones 'needs' in the water and as well as bringing women to the islands such as Nosy Sarotsy, Rehampy and Nosindambo are taboos.

nets (> 100 m) with small mesh that were confiscated by both Associations. The poachers' main objectives for this unconventional method of taking fish was to use them for the practice of fish salting to be sold to middle men in Morondava (about 200 km to the south) or in Antananarivo (about 900 km east). In collaboration with Commune of Trangahy, Soatana village elders, The Peregrine Fund technicians, Forestry Representatives from Antsalova and the FIFAMA Association has controlled Ankerika Lake. On 11 August 2005 at a clandestine camp at Betangiriky one person was caught preparing salted fish. This person's illegal net was burned by the Association's resource controllers on 13 August 2005 so he couldn't reuse it. One month later, this person paid his traditional fine of one zebu cow and 20 liters of rum to the FIFAMA Association. However, in the same year,

TABLE 2. The number of fishermen, fishing season opening and closing dates and fish yields at the Manambolomaty Lakes site from 2002 to 2007 (* Only from Soamalipo/Befotaka in the FIZAMI. Drought affecting the Antsalova region in 2004 may have impacted the fish harvest; †: Regional drought was also coincided with the death of Ankerika Tompondrano in earlier January 2005; - Data deficiency)

Year	Fishermen (numbers)	Opening fishing season (FIZAMI/FIFAMA)	Season closes for both Associations	Fish yield (tons)
2002	196	-	30 November 2002	93
2003	266	-	30 November 2003	89
2004	262	(8 June 2004 / -)	30 November 2004	116
2005	213*	(28 June 2005 / 12 August 2005)	30 November 2005	34†
2006	265	(23 June 2006/11 August 2006)	30 November 2006	67
2007	298	(2 June 2007 / 08 June 2007)	30 November 2007	200

controllers composed of the Commune Rurale of Masoarivo, The Peregrine Fund technicians, and a Forestry Representative from Antsalova helped the FIZAMI Associations to control Soamalipo and Befotaka Lakes and two consecutive visits were made to the Betangiriky illegal camp on 13 July and 14 August 2005. Twelve illegal nets greater than 100 m in length and with small mesh belonging to unknown owners, 15 baskets (60 cm x 60 cm) of salted fish and 15 bags of salt (60 cm x 40 cm) were found and confiscated during the initial visit to this camp. All nets were destroyed by burning on 15 August 2005, and all salted fish and salt were given to the Masoarivo Commune to be sold with the money collected from this sale going to the community treasury. Although it is well stated in the Association charters that Masoarivo Commune is the supporter of the FIZAMI Association regarding wetland management objectives and activities, the Mayor from this commune has remained aloof because of possible corruption charges tied to him, as he was supposedly bought by the persons who were salting fish. In fact, four persons were caught by the FIZAMI Association during their second visit. They found fish that had been salted and unfortunately, this went unpunished. To date, the traditional fine of one cow and 20 liters of rum remained unpaid. Fortunately, the ban on using live trees as firewood has been fully respected as fishermen have always used firewood from dead trees for drying their fish. Until now, the only unacceptable practice by fishermen is the length of their nets and this remains the greatest issue at the Manambolomaty Lakes site.

THREATENED SPECIES PROTECTION As part of wetland ecosystem, several threatened taxa have also benefited from Manambolomaty Lakes RAMSAR site management. Taboo enhancement is useful tools for threatened species conservation, as noted Colding and Folke (2001). In an analysis of 70 specific species-taboos, about 30 %, predominantly mammals and reptiles were found to involve species recognized as Threatened by The International Union for the Conservation of Nature (IUCN) (Colding and Folke 1997). Hunting of threatened animals has therefore declined at the Manambolomaty Lakes site since the commencement of GELOSE in 2001. As umbrella species, conservation of Madagascar fish eagles has helped protect many other threatened species and wetland ecosystem as whole. As source of local meat and for compromising the social convention restriction, introduced Bush pigs (*Potamochoerus larvatus*) have been hunted throughout the year and it can be hunted during different life stages to minimize its impact on community's crops, as stated by one of FIZAMI member (M. Mahasaky pers. com.). To prevent the detrimental harvesting of Common tenrecs (*Tenrec ecaudatus*), they are hunted for local consumption only during the non-breeding season. This protein source mitigation has allowed some threatened species to have good conservation status. Although some lemur traps were sometimes found in the forest, and a carapace of a Big-headed turtle near some settlements (J. Rabearivony pers. obs.), this wetland site is important in maintaining biodiversity (Dodman et al. 1999, Rabarisoa 2001, Razafimanjato et al. 2007). The polyandrous Madagascar fish eagles have been stabile at 9-12 breeding pairs (Table 3). Pairs were defined as the number of females that occupied a nest site. In Manambolomaty Lakes about 70-80 % of nests contain two males and one female. Manambolomaty Lakes has one of the highest concentrations of breeding fish eagles in Madagascar (Figure 3), representing about 10 % of the remaining population in the world (Watson and Rabarisoa 2000). Many other threatened waterbirds are also protected at this site (Razafimanjato et al. 2007). The organization of fishermen within five specific camps in Soamalipo / Befotaka – two permanents and three temporary – and three in Ankerika with only one permanent have minimized human disturbances and helped to protect the threatened species. Looking at an important plant species of the Tsimembo Forest, the endemic Hazomalany tree (*Hazomalania voyroni* Hernandiaceae) is important to the culture of *Sakalava* people for making traditional coffins (TPF and DWCT 2003).

TABLE 3. Number of Madagascar fish eagles at the Manambolomaty Lakes site from 2002-2007

Madagascar Fish Eagles	Year					
	2002	2003	2004	2005	2006	2007
Male (n)	18	18	19	18	20	20
Female (n)	9	9	11	11	12	11
Total	27	27	30	29	32	31

WETLAND INTEGRITY AND UNIQUENESS No traces of slash-and-burn agriculture have been documented within the main Tsimembo Forest managed by the FIZAMI and FIFAMA Associations. Such agricultural practice was devoted to *Ziziphus mauritania* (Rhamnaceae – introduced tree species) forest (TPF and DWCT 2003). Control of illegal camps was one of the tasks of the Associations and forestry representatives from Antsalova, the nearest district town. An illegal camp in Bekofoky (Ankerika), for instance, was removed in August 2005. The 8th legal camp at Akoririky was also removed in 2004 because fishermen were deforesting a 65 m x 20 m area for extending the camp without the Association's permission. This deforestation altered wetland

FIGURE 3. The endemic and critically endangered Madagascar fish eagle (*Haliaeetus vociferoides*). The Manambolomaty Lakes site has one of the highest concentrations of breeding fish eagles in Madagascar.

ecosystem integrity and beauty. No forest fires have been recorded since the start of the GELOSE process in 2001. Taboos regarding carrying live charcoal embers on the water as well as bringing women to the islands of Sarotsy, Rehampy and Nosindambo of the Manambolomaty Lakes have been well respected by the fishermen. These acts are considered 'religious taboos' and linked to the sacredness of the areas (Colding and Folke 2001). These taboos have helped in contributing to the maintenance and protection of the biological diversity and habitat for threatened species (Gadgil 1987). These islands are isolated, not occupied by humans and are part of several Madagascar fish eagle home ranges. Apart from one permanent nest of Madagascar fish eagles at the island of Nosindambo, it also contains the largest population, more than 1,000 individuals of the Madagascar flying fox, a vulnerable Madagascar endemic bat species (Jenkins et al. 2007). Therefore, the maintainance of wetland integrity and beauty is supported by species-specific and habitat taboos that are considered as 'non-use taboos' of resources for strengthening the 'preservationist ethic' (Muir 1916, Harris 1979, Colding and Folke 2001).

BEYOND BIOLOGICAL CONSERVATION MILESTONES For the sustainability of common property management, biodiversity conservation should be coupled with rural economic development (Child 1996). We selected here the main economical and biological conservation milestones of FIZAMI and FIFAMA associations regarding Manambolomaty wetlands management.

In 2002, both Associations opened bank accounts in Morondava (the nearest financial town) by depositing money they had collected from issuing fishing permits in their resource management zones. These bank accounts for both Associations continue to grow from the resource use permits. In 2004, the Associations bought with their funds rice stock to sell to local community members at a reduced rate during the annual rice shortage period (November to April), thus providing a tangible benefit to the communities for managing their fisheries and forest resources.

In 2003, 1,214 tree seedlings of *Commiphora* spp. Burseraceae – plant species that can be used for plank making – were raised in a local nursery built by the associations with 1,184 transplanted to several openings and degraded areas around the three lakes. A management area boundary was demarcated and marked with cement blocks at trail and road crossings and a management perimeter line was cut 1.5-2 m wide by 54 km long.

In 2004, offices were built for each Association in the village of Ankirangato for FIZAMI and village of Bejea for FIFAMA, with funding from RAMSAR and logistical assistance from The Peregrine Fund. Also in 2004, the two Associations received 'Gift to the Earth' awards from the World Wildlife Fund for Nature for their pioneering role in applying and succeeding in Madagascar's localized resource management (GELOSE) control, sustainable resource use and biodiversity conservation.

From 2005-2015, the two Associations became the first recipients in Madagascar of a 10-year management period from the Malagasy government. They are being supported by the National Forestry and Fisheries Departments, local authorities, police and judicial personnel, and along with continued support and assistance from The Peregrine Fund.

From 2006-2010, the Associations have issued fishing permits covering a 4-year period (September 2006 to September 2010) which has been developed and supported by the regional representative of the Madagascar Fisheries Department. In 2006, the two Associations, FIZAMI and FIFAMA, and the two Communes, Masoarivo and Trangahy, received from the RAMSAR organization communication materials such as solar panels and several accessories for the single-sideband modulation (SSB) radio to improve their existing erratic functioning communication equipment.

In 2007, United State Agency Aid and Development (USAID) in Madagascar expressed their satisfaction towards the Associations' wetlands management by constructing four wells, two in Trangahy and Masoarivo Communes respectively, for providing clean potable water in the area. On behalf of a consortium of three Associations, FIZAMI, FIFAMA and SAMAKA (*Sakaizan'ireo Aina Misy ao Antsamaka Kajiana ho Anto-pivelomana*), the Madagascar National RAMSAR organization awarded to the 'Local RAMSAR Committee', known locally as *Komity Mpitantana Sity RAMSAR* (KMSR) and the three Associations, FIZAMI, FIFAMA and SAMAKA, an office constructed in the Masoarivo Commune during 2007 as their contribution for supporting their conservation efforts in the Manambolomaty Lakes region.

DISCUSSION

The success of Manambolomaty Lakes wetland management undertaken by FIZAMI and FIFAMA could be considered as the results of strong involvement of all stakeholders and collaboration between the Associations, local authorities and technical supports from regional forestry and fishery representatives and The Peregrine Fund. This collaboration has made the Manambolomaty Lakes fishery management ecologically durable and economically viable.

SUSTAINABLE MANAGEMENT OF LOCAL FISHERY The world's fisheries have shown drastic declining catches per effort in association with over-fishing by humans (da Silva 2002, von Sarnowski 2004). In many of Madagascar's lakes, over-fishing is associated with unsustainable harvesting methods and little respect for traditional rules and taboos (Razafiarisoa 1995). In Alaotra Lake (central eastern Madagascar), for instance, nets with small meshes (in Malagasy *ramangaoka*) have previously been used (Razafiarisoa 1995). The lack of respect for local taboos by 'new migrants' from other regions (e.g. Itasy, Alaotra and Mantasoa) relative to traditional fishery management in Kinkony Lake, northwestern Madagascar, is one example of a local fisheries declining trend (Razafiarisoa 1995).

In 1990s, detrimental harvesting methods and the disobeying of taboos were also frequently encountered in Manambolomaty, especially prior to GELOSE era (TPF and DWCT 2003). Fortunately, Manambolomaty Lakes Community-Based Wetland Conservation began in 2001 and fish resources were rapidly re-established through the regulation of resource withdrawal and withdrawal methods as well as access to resources in time (Tables 1-3) (*Tompondrano* pers. com.). As the annual weight or number of fish caught is one of the standard indicators of biological yields status (Hilborn and Walters 1992), stability of Manambolomaty Lakes fish yields (at 60-100 tons per year) in 2002, 2003 and 2006 showed the ability of two existing Associations, FIZAMI and FIFAMA, to mange their natural resources. In very rainy years, respectively in 2004 and 2007, yields reached up

116 tons to 200 tons. Many fishes from higher altitude rivers and lakes (e.g. Ankakobo) might have been carried downstream into the Manambolomaty Lakes. The lowest fish yields were in 2005, which sadly coincided with the death of the Ankerika *Tompondrano* 'keeper of the lake' and obviously impacted and disrupted wetland management until a replacement was found in 2006.

Madagascar's first settlers – through hunting system – were probably responsible for recent extinctions of several lemur species, at least 17 taxa according to Godfrey and Jungers (2003). Recently, poaching of protected and endemic fauna living within protected areas had become more prevalent (Goodman 2000, Garcia and Goodman 2003, Patel et al. 2005). Forest degradation in the form of slash-and-burn agriculture and conversion of natural habitat into cattle pastures are the two major threats to Malagasy biodiversity (Goodman 2006), while local extirpations of threatened fauna – including turtles, birds, primates, fruit bats and carnivores – are associated with hunting (Garcia and Goodman 2003, MacKinnon et al. 2003).

Accordingly, the local Associations FIZAMI and FIFAMA have established unique indicators in order to measure their management efficiency. These indicators include (i) forest surrounding the wetland sites remains intact and no trace of human-caused forest fire occurs; (ii) site contains seven lemur species and at least 40 waterbirds species; (iii) the number of Madagascar fish eagles remains stable at 10 pairs; (iv) annual fish yields is more than 45 tons; and (v) the population of the Big-headed turtle (*Erymnochelys madagascariensis)* represents all age class (adult, juvenile and hatchling). The first four indicators have been achieved successfully by these Associations (e.g. Watson and Rabarisoa 2000, Razafimanjato et al. 2007). Regarding Big-headed turtle restoration, it has been suggested to achieve the zoning of some parts of the lake and lake shore as breeding site for this species (R. Lewis pers. com.). This turtle breeding area would be prohibited from fishing activities, thereby allowing the population to increase. Locally, eggs and adults of this species are taken as sources of protein. Hence, whilst this zoning requires full consensus from local communities and is technically dependent on local and / or regional Fishery Representatives; all other protected fauna are in good conservation status and wetland ecosystem as a whole are generally healthy. As such, the Manambolomaty Lakes is one of the best proposed sites in Madagascar to be added into the existing protected area network (Randrianandianina et al. 2003). This zoning will be one of the main activities undertaken in 2008 after permanent protected status of the Manambolomaty Lakes. This requires full participation of The Durrell Wildlife Conservation Trust (DWCT), the organization with specialists in turtle conservation working in the Antsalova area. As far Manambolomaty Lakes, it would be an important Malagasy site for International Heritage candidate because of its wetland ecosystem integrity, its endemic and threatened taxa and recreational aspects, concluded M. Nicoll (pers. com.).

ECONOMIC VIABILITY It is premature to say if Manambolomaty Lakes fisheries has had a positive impact on the local economy, but Watson and Rabarisoa (2000) estimated annual fish harvest was worth about $479,495 US which represents about $1,562 US / fishermen per season. Given the local current price of dried fish (about $2 US / kg), the annual revenue of the local communities is increasing. Currently, it is estimated that about 56 % of the two local Commune's budgets, Trangahy and Masoarivo, are being collected from the tax of fish sales to wholesale fish buyers.

Direct benefits to local economies and other forms of development stated in Madagascar's Action Plan (MAP), a 5-year plan (2007-2012) for developing Madagascar, have also been initiated at the Manambolomaty Lakes site. Like other western regions in Madagascar, diseases from unsafe water (e.g. bilharzias, diarrhea) occur in many areas surrounding the Manambolomaty Lakes. Since social life improvement is one target area under the System of Protected Areas of Madagascar (SAPM) and MAP, wells have contributed largely to decreasing diseases from unhealthy drinking water. Strengthening the educational system at primary schools is a way to reduce poverty and is one of Madagascar's commitments. We continue supporting all primary schools in the Manambolomaty Lakes area (e.g. Amberegny, Masoarivo, Ambalamanga, Soatana and Trangahy) by providing school materials (e.g. notebooks, pencils, pens, chalk and chalkboards) to local students. We also provide support in the Melaky regional sporting events, like the *Jeux de Melaky*, to complement school education in the area. Currently, of 1,184 trees transplanted, 80 % continue to grow (TPF and DWCT 2003). This contributed largely to the Madagascar's 'green revolution' by putting value back into non-forested land. Transplanting trees will slow down the impact on trees by communities in the Tsimembo Forest. Infrastructure setting is part of national government in Madagascar. Three associations' offices were built around Manambolomaty RAMSAR site for this purpose for FIZAMI, FIFAMA and the Local RAMSAR Committee (KMSR). These facilities have helped the local Associations to administer their wetland management. Communication materials such as solar panels and several accessories for the single-sideband modulation radio were given to the Trangahy and Masoarivo Communes. Beyond fishery management sustainability, these direct and indirect benefits are demonstrating the economic viability of wetland management undertaken by FIZAMI and FIFAMA in the Manambolomaty Lakes area.

CONCLUSION

The positive performance of the FIZAMI and FIFAMA Associations in Community-Based Wetlands Conservation at the Manambolomaty Lakes site has become well known in the conservation circles within Madagascar; and the model established by The Peregrine Fund has been copied and applied to many by other organizations in similar situations throughout the country. In 2005, for instance, a team from Missouri Botanical Garden (MBG) working in Mahabo, southeast Madagascar, visited the Manambolomaty Lakes site to learn and to do an experience of exchange on how FIZAMI and FIFAMA Associations used their taboos and social conventions to manage the Manambolomaty Lakes wetlands and forest. This exchange of information and experience was requested by their founder, Liz Claiborne and Art Ortenberg Foundation, for the sustainable use of plants species utilized by a Women's Association developing a basket making art for the international market. The only issue faced by FIZAMI and FIFAMA Associations in this management system was the interference caused by a few local politicians who were supporting a minority local group, and especially the migrants of the area that were not abiding to the local traditional rules, taboos and conservation policies. As the current Madagascar's national program is to increase in number and surface of

Protected Area (PA), we would suggest at each new specific site the strong consideration of taboos and social conventions for achieving the management purposes. Although this approach may sometime fail to protect certain endangered Malagasy species – example, *Hapalemur alaotrensis* (Durbin et al. 2003, 2008) – our findings corroborated the previous researches in Madagascar (e.g. Lingard et al. 2003, Watson et al. 2007), and worldwide (Colding and Folke 2001) that are supporting the taboos and social conventions enhancement are the efficient tools for conserving endangered species and ecosystem as a whole, as it is economically viable and ecologically durable.

ACKNOWLEDGEMENTS

The Manambolomaty Lakes wetlands conservation project was funded by Liz Claiborne and Art Ortenberg Foundation. Financial support for conservation mitigation and alternative development was given by the RAMSAR International via Madagascar CONARAMS (Comité National RAMSAR). Technical support from local and national representatives of the Ministry of Environment, Water and Tourism was greatly appreciated. Special thanks to Gisitera of the Antsalova Forestry Department for his energetic field activities. The FIZAMI and FIFAMA associations as well as their respective 'keepers of the lakes' (*Tompondrano*) are also acknowledged here for their understanding and collaboration with the project. The RAMSAR management plan was developed in collaboration with The Durrell Wildlife Conservation Trust (DWCT) and Programme Bemaraha. FIZAMI and FIFAMA had full management support from KMSR, especially President Solofo Félix Armand. Field data were collected by The Peregrine Fund's local technicians. Manambolomaty Lakes map was kindly prepared by Marius Rakotondratsima.

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Three flying fox (Pteropodidae: *Pteropus rufus*) roosts, three conservation challenges in south-eastern Madagascar

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ABSTRACT

We visited three roosts of the Madagascar flying fox *Pteropus rufus* in December 2005 in the Anosy Region. Colony size was 900 at Berenty Private Reserve, 412 at Amborabao and 54 at Sainte Luce, based on single counts at each site. Hunting at the roost is prohibited at Berenty but *P. rufus* is trapped at night in the area surrounding the reserve, where it feeds on sisal. At Amborabao, the bats roost in a sacred forest and hunting is forbidden. At Sainte Luce, the forest is highly degraded and the bats are hunted frequently, despite efforts to engage the local community in forest conservation. Questionnaires with people living near the roosts revealed the flying foxes were regarded as pests of litchis in Amborabao and Sainte Luce. Berenty is the only site where tourists are able to observe roosting *P. rufus*. The role of sacred forests and local taboos (*fady*) is very relevant for *P. rufus* conservation and might be the only practical mechanism in sites where legislation on hunting and land use is not being enforced.

RÉSUMÉ

Trois gîtes de *Pteropus rufus* ont été visités dans la région Anosy en décembre 2005. La population était composée de 900 individus à Berenty, 412 à Amborabao et 54 à Sainte Luce, le comptage ayant été fait une seule fois dans chaque gîte. La chasse au dortoir est interdite à Berenty mais *P. rufus* est capturé la nuit, lorsque les individus se nourrissent dans les plantations de sisal environnantes. A Amborabao, le dortoir se trouve dans une forêt sacrée où la chasse est interdite. A Sainte Luce, la forêt est extrêmement dégradée et les chauves-souris sont chassées fréquemment malgré les efforts pour impliquer la communauté locale dans la conservation de la forêt. Les interviews avec les gens vivant près des dortoirs ont montré que les *P. rufus* sont considérés comme nuisibles car consommateurs de fruits de litchis à Amborabao et Sainte Luce. Berenty est le seul site où les touristes peuvent observer *P. rufus* au dortoir. Les forêts sacrées, les croyances locales et les tabous (*fady*) sont importants pour la conservation de *P. rufus* et pourraient être les seuls facteurs pour expliquer le respect des régulations cynégétiques et foncières.

KEYWORDS: Madagascar, *Pteropus rufus*, roost, Tolagnaro

INTRODUCTION

The conservation of the Madagascar flying fox *Pteropus rufus* poses a major challenge because even though it is a threatened species (IUCN 2007) it is not fully protected by Malagasy law and can be legally hunted by people for food between May and September (Durbin 2007, MacKinnon et al. 2003, Racey et al. in press). In practice however, people either deliberately ignore or are unaware of the hunting season and *P. rufus* is widely exploited throughout the year and this is believed to be causing some colonies to abandon traditional roosts (MacKinnon et al. 2003, Racey et al. in press). Roosting and foraging sites are also threatened by the degradation of native forests, a situation exacerbated by the tendency for *P. rufus* to use small forest patches outside of protected areas (Jenkins et al. 2007ab, Racey et al. in press).

Colonies of up to 5,000 *P. rufus* have been recorded in Madagascar (MacKinnon et al. 2003) and roosts are attractive to hunters because of the concentration of bats. However, roosts should also be important conservation sites for bats in Madagascar because they present a viable focus for monitoring and protection (Goodman et al. 2005).

Previous studies on the ecology of *P. rufus* in the Anosy Region have demonstrated that it has a varied diet that includes exotic plants and that it plays an important role in seed dispersal (Bollen and van Elsacker 2002, Raheriarisena 2005, Long and Racey 2007). As part of a regional programme to assess the status of flying fox colonies (Jenkins et al. 2007b) and to determine the local anthropogenic factors that influence the conservation of roosts we made a rapid survey of three sites.

STUDY SITE Roosts were surveyed at Berenty Private Reserve (referred to as Berenty hereafter), Amborabao and Sainte Luce over a three-week period during December 2005 (Figure 1). Berenty (Malaza forest S25°00', E46°18'), 85 km west of Tolagnaro, is a ca. 200 ha fragment of gallery forest on the Mandrare River and is a major tourist attraction because of its tame lemurs. The roost at Amborabao (Mahanoro Forest S24°49', E47°02'), 27 km northeast of Tolagnaro, is in a small

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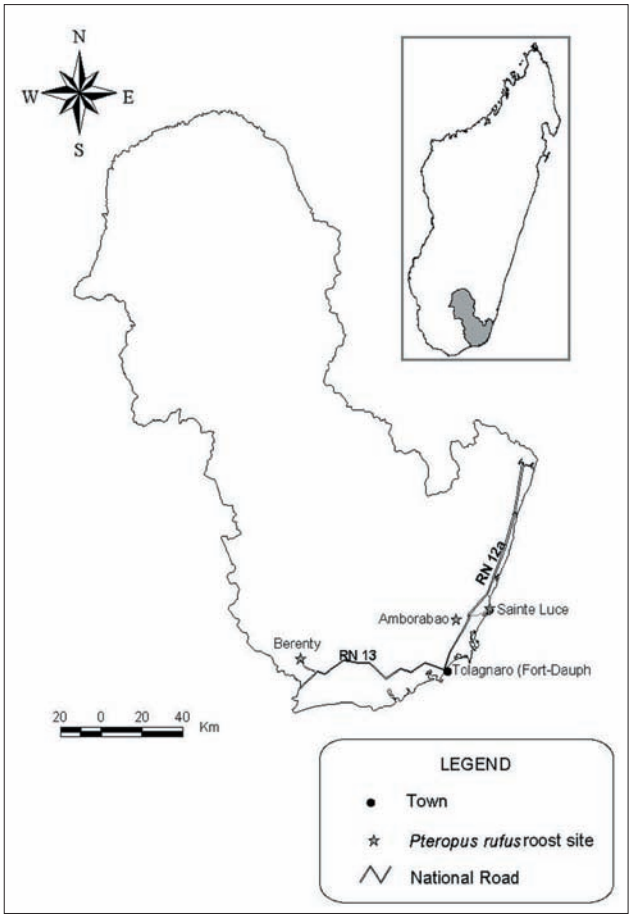

FIGURE 1. Map showing the three forests with roosting colonies of the Madagascar flying fox *Pteropus rufus* in the Anosy Region (shaded) of southeastern Madagascar.

forest considered sacred by local inhabitants. Sainte Luce (Etazo forest S24°48', E46°18') forest, 50 km northeast of Tolagnaro, is highly fragmented and the *P. rufus* colony is currently found in a small fragment identified as S7 and the nearby S6 fragment is no longer used by the bats.

METHODS

We estimated the size of the *P. rufus* populations by counting the bats as they dispersed from each roost on a single evening (1830 - 2000 h) and also by counting flying and roosting bats the following morning (0800 - 1000h). During the evening counts, two observers (VNR and DA) were stationed at separate vantage points that facilitated good views of dispersing bats and number of bats leaving the roost was counted until a 30 minute period elapsed with no bats flying from the direction of the roost. The morning survey was undertaken by the same observers who scanned each roost tree and counted all visible bats with the aid of binoculars.

The inhabitants of villages surrounding the roosts were interviewed by one of us (VNR) to record local perceptions of fruit bats. All interviewees were questioned individually but no specific method was adopted for the selection of interviewees but every effort was made to sample a range of households within the study villages.

RESULTS

The largest colony, with over 900 bats at the time of our visit, was at Berenty and the smallest, with only 54 bats, was at Sainte Luce (Table 1). There was a notable difference between the proportion of the colony that was observed during the dispersal and roosting counts, with 87 % of bats at Sainte Luce leaving the colony during our nocturnal observation period but only 11 % and 20 % at the other two sites (Table 1).

The owner of Berenty had prohibited tree cutting and animal hunting within the reserve and access by local people is restricted (Table 1). Some tourist groups are shown the *P. rufus* roost from a vantage point approximately 100 m from the roost during guided tours of the forest reserve. There is also an interpretation board with some information about *P. rufus* on the trail that passes close to the roost. The roost is therefore well protected from both hunting and other types of disturbance.

The fragment at Sainte Luce is frequently accessed by villagers who traditionally visit the forest to hunt animals, extract wood and search for non-timber products. With support from conservation partners and a mining company, the local community around Sainte Luce has created a social contract (*dina* in Malagasy) to manage the forest but this does not yet appear to have conferred significant benefits to the *P. rufus* colony, which was still small on a visit in May 2008 (D. Andriafidison pers. obs).

The presence of a cemetery in the Amborabao forest fragment protects the *P. rufus* because cultural sensitivities prohibit the hunting of bats at the site. The collection of dead wood in the forest though, is tolerated by the local community association communauté locale de base (COBA) that manages the forest (Table 1). Thus although the bats are not hunted the colony is frequently disturbed. This colony is located less than one kilometer from the Tsitongambarika forest and members of the COBA reportedly ensure that the traditional rules governing access to and use of non-timber resources are upheld.

A total of 205 people participated in the questionnaires and discussions and sample size varied between sites because of logistical reasons (Table 2). Respondents near Berenty were a mix of Antanosy and Antandroy people but the other two sites consisted entirely of the former ethnic group. The percentage of people who admitted to hunting *P. rufus* was notably higher in Amborabao and Sainte Luce than near Berenty. However there was less difference in the percentage of people who had eaten fruit bats at each site, varying between 40 % and 50 %.

TABLE 1. Three *Pteropus rufus* roosts in the Anosy Region, Madagascar, assessed during December 2005

	Fragment size (ha)	Dispersal counts	Roosting counts	Distance to village (km)	Hunting permitted in roost	Evidence of hunting found in roost	Hunting reported from roost	Village access to the forest
Berenty	200	184	903	2.2	No	No	Yes	No
Sainte Luce	225	47	54	4.5	No	No	Yes	Yes
Amborabao	180	46	412	0.6	No	No	No	Yes

TABLE 2. Summary of a questionnaire about *Pteropus rufus* from three villages located near roosts (N = number of respondents). Question 4 only concerns those people who answered 'yes' in question 3. Question 5 only concerns those people who answered 'no' in question 3

		Berenty		Sainte Luce		Amborabao	
		N	%	N	%	N	%
1. Ethnic group	Antanosy	18	40	80	100	80	100
	Antandroy	27	60	0	0	0	0
2. Do you hunt *P. rufus*?	No	42	93	55	69	40	50
	Yes	3	7	25	31	40	50
3. Have you eaten *P. rufus*?	No	27	60	42	53	40	50
	Yes	18	40	38	47	40	50
4. Frequency:	All year	4	29	21	55	32	80
	Sometimes	14	71	17	45	8	20
5. Reasons for not eating	Taboo (*fady*)	24	89	0	0	40	100
	Religion	3	11	0	0	0	0
	Never trapped	0	0	40	95	0	0
	Frightening	0	0	2	5	0	0
6. Heard about bat conservation?	No	0	0	80	100	80	100
	Yes	45	100	0	0	0	0

From the sample of people who consumed *P. rufus* those at Berenty appeared to only do so occasionally whilst consumption occurred more regularly at the other sites. At all sites people preferred to eat *P. rufus* when the bats were fat and when other sources of protein were scarce. Taboos were mentioned near Berenty and Amborabao as the primary reason for not eating *P. rufus*, the former associated with ethnicity and the latter with a burial site. At Sainte Luce it appeared that those who had not eaten bats had never trapped them or otherwise had the opportunity to obtain them. We were unable to obtain detailed information on previous environmental education efforts but we were aware of an attempt near Berenty and Sainte Luce to inform people about conservation. In the survey, only the people near Berenty had been exposed to the notion of bat conservation.

Hunters at Berenty reported using nets at nocturnal feeding sites situated outside the reserve to trap *P. rufus* feeding on sisal. A hunter can expect to catch 8 to 12 bats per week between September and May and 25 to 30 between June and August. Live bats are sold discretely in villages around the reserve for between 1,400 MGA and 2,000 MGA each ($ 0.9-1.3 US). At Sainte Luce and Amborabao, fruit bats are hunted at night by local people between December and February when the bats feed on cultivated fruits (e.g. *Litchi chinensis* Sapindaceae) and other plants (e.g. *Typhonodorum lindleyanum* Araceae) or during June and July when Kapok trees (*Ceiba pentandra* Malvaceae) are in flower. Questionnaires revealed that Sainte Luce was the only roost directly targeted by hunters during day. Firearms are used by hunters who make day trips from Tolagnaro.

DISCUSSION

This short study draws attention to the challenges associated with conserving the Madagascar flying fox *P. rufus* and uses examples from three different roosts to present some of the most common threats to the species in south-eastern Madagascar. All three roosts receive different forms of protection, ranging from owner-imposed regulations on private land, to ancestral traditions and locally generated rules designed to encourage sustainable forest management. Whilst it is not unusual for *Pteropus rufus* roosts to be associated with forests of cultural importance and a few other colonies have *dinas* (Jenkins et al. 2007a), the majority of sites in Madagascar are without any protection (MacKinnon et al. 2003).

Pteropus bats are a traditional source of meat for people throughout most of their range (Mickleburgh et al. 1992). In many island states there is demand for flying fox meat and the off take is considered to be threatening the survival of a range of species (Brooke and Tschapka 2002, Struebig et al. 2007). In Madagascar, hunting is one of the main threats to *P. rufus* and occurs in many parts of the island where these bats can be observed for sale in markets or served in restaurants (Jenkins and Racey this volume). Although hunting only occurred at one of the roosts in our study site, the bats were trapped in the vicinity of all three roosts. Trapping appeared to coincide with periods when the bats fed on plants near villages and were thus relatively easy to catch; there was no evidence therefore that people respected the legal hunting season per se. Bats were hunted both for subsistence and commercial purposes although there are insufficient data to assess the sustainability of the harvest or the socioeconomic importance of the meat. Locally managed harvests of foraging bats may be a viable option in some parts of Madagascar (Jenkins and Racey this volume), but hunting at roosts sites causes severe disturbance and should be prohibited (Racey et al. in press). Considerable further study is needed on *P. rufus* roosting dynamics, harvest patterns and local resource governance options before regulated harvests can be promoted.

The loss and degradation of native forest habitats is a major threat to *P. rufus* roosts (MacKinnon et al. 2003, Jenkins et al. 2007a). Roost occupancy by *P. rufus* varies temporally in areas of high disturbance (Jenkins et al. 2007a) and both the

Sainte Luce and Amborabao forest fragments have only been occupied in recent years following disturbance and degradation at nearby traditional roosts. This indicates a certain resilience to roost perturbation as long as alternative sites are available in the vicinity, although there may be other impacts on the bats, such as to social organization or behaviour that are not immediately discernable following roost switching. The Sainte Luce fragment will be cleared for forest in the next 40 years by a mining company and it might be instructive to follow the impact of this disturbance on the colony by marking and radio tagging the bats.

Because *P. rufus* roosts in small fragments or gallery forests that are usually without protected area status their persistence at any given site is often precarious. Gallery forest is an important habitat in other countries (e.g. Ukizintambara et al. 2007) and should be included in conservation plans in Madagascar. Sacred forests, which are usually small and isolated, also provide important roosting habitats for *P. rufus*. Significantly, whilst small sacred or gallery forests might be relatively poor in overall biodiversity terms compared to intact forest, they provide an important refuge for species which are not found in large forest blocks and that play key ecological roles in the ecosystem. In other parts of the tropics, sacred forests have an established importance in biodiversity planning across fragmented landscapes (e.g. Decher and Bahian 1999, Wadley and Colfer 2004) and in Madagascar where most existing protected areas are large (ANGAP 2003) local taboos protect resources in small forest patches that would otherwise be openly exploited (Tenbö et al. 2007).

Berenty is a major tourist attraction and in 2005 received approximately 600 visitors per month between August and September (Rahaingodrahety 2007). This reserve is famous for its lemurs but it is not clear what percentages of the tourists also visit the *P. rufus* roost. Ecotourism might provide the right economic incentives at other locations and thus benefit local people as well as the bat roosts. The Amborabao roost has some ecotourism potential because the hillock adjacent to the forest provides a suitable vantage point from where the bats can be viewed with a telescope or binoculars. However, the lack of alternative attractions in the area is likely to prohibit this site from being developed for tourists and Sainte Luce is too remote for ecotourism purposes and the colony is not large or stable enough.

In both Amborabao and Sainte Luce fruit bats are considered as pests of litchis and some of the hunting could be attributed to pest control measures. At Amborabao we encountered some resentment to the traditional protection afforded to the fruit bats from the sacred forests as it was perceived to be sustaining high depredation rates on local litchi crops.

Culture and taboo can impact two aspects of flying fox conservation. Firstly, forests that are considered sacred for mystical or burial reasons are often protected by local people and this is particularly true for southern Madagascar (Tenbö et al. 2007). Although the actual rules that govern the type of protection vary on a site by site basis, flying fox hunting is usually prohibited at these sites. This was the case for Amborabao where limited access by local people is permitted but flying fox hunting is strongly discouraged. As the flying foxes only arrived at this site recently it is important to recognize the value of working with village groups because in many cases traditional beliefs are open to new interpretation or dilution through demographic mixing (Banks et al. 2007). The value of conveying the ecological importance and conservation status of threatened flying foxes to local communities and the general public is well established in the western Indian Ocean (Trewhella et al. 2005). In the Anosy Region, additional support to community groups in the form of awareness raising will benefit *P. rufus* conservation and assist the preservation of traditional taboos and beliefs.

The other impact of culture and taboo is on hunting and consumption of *Pteropus* bats. In many parts of Madagascar local taboo (or *fady*) governs resource use and can benefit species conservation because certain taxa are forbidden to be hunted or consumed (e.g. Jones et al. 2006). In our study there was some evidence for this because the Antandroy people rarely ate *P. rufus* because it was taboo. In other circumstances, taboo might not determine which species are eaten but it may impact the way in which the animal is exploited (e.g. Jones et al. 2006). However, in many areas *fady* is being eroded and as this occurs the animals that were once traditionally protected are exploited (e.g. Mutschler et al. 2001).

RECOMMENDATIONS

1. Conduct conservation relevant research on *P. rufus* that will lead to policy recommendations to ensure protection of the species and with the ecosystem services it provides.
2. Detailed study of the hunting and consumption of flying foxes by people to determine the importance of bat meat in cultural and socioeconomic contexts, as well as the ratio hunting for subsistence and commercial purposes.
3. Assess whether roosts are large enough to sustain managed harvests of bats trapped whilst foraging at night and whether such initiatives would benefit conservation.
4. Improve the viewing experience at Berenty by creating a new poster that would provide greater information to the guides and encourage more tourists to request a visit to the roosts and also consider a remote video camera that would allow researchers and tourists alike to view bat behavior on screens in the reserve buildings.
5. Investigate the actual economic losses to growers of litchis and other commercial crops that are directly attributable to *P. rufus* in order to assess whether the species should be treated as a pest.
6. Achieve enhanced community engagement in fruit bat conservation through a monitoring project conducted by local people and supervised by conservation technicians with the possibility of some tangible reward available for the village if the roost is conserved.
7. Awareness raising and environmental education on *P. rufus* in villages/schools on the ecosystem services the species provides.

ACKNOWLEDGEMENTS

This study was funded by the Rio Tinto Fauna and Flora International Biodiversity Partnership, the Darwin Initiative and the BP Conservation (Leadership) Programme. We are very grateful to QMM for assisting us with the project and are indebted to the people who voluntarily contributed information. Emma Long

and an anonymous referee helped to improve an earlier version of the manuscript. Hanta Julie Razafimanahaka translated the abstract into French.

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Bats as bushmeat in Madagascar

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ABSTRACT

Bats are eaten by people throughout Madagascar and although the larger species like *Pteropus rufus*, *Eidolon dupreanum*, *Rousettus madagascariensis* and *Hipposideros commersoni* are preferred, small insectivorous bats are also eaten. The national hunting season for bats is widely ignored and both unsuitable hunting practices and high offtake represent a serious threat to bat populations in some areas. Bat bushmeat may be an important source of protein for Malagasy people during periods of food shortage but in general there are few data on the socio-economic and cultural importance of bats. Fruit bats produce a single offspring per year and are therefore susceptible to over-hunting. Nevertheless, large roosts offer the possibility of community managed harvests to secure the colony and provide a source of meat but further research is needed before this can be considered. Roost sites also present the best focus for conservation and greater effort is needed to control hunting using existing legislation and flexible community-based solutions that are sensitive to the local context. The threat of pathogen transfer from bats to people is of growing concern as more bat species are identified as vectors of emergent viral diseases.

RÉSUMÉ

Les gens consomment des chauves-souris partout à Madagascar et s'ils préfèrent les plus grandes espèces comme *Pteropus rufus*, *Eidolon dupreanum*, *Rousettus madagascariensis* et *Hipposideros commersoni*, les petites chauves-souris insectivores sont également consommées. La période d'ouverture nationale de la chasse n'est généralement pas respectée et l'on assiste aussi bien à de mauvaises pratiques cynégétiques qu'à des prélèvements importants qui représentent une menace sérieuse pour les populations de chauves-souris dans certaines régions. Les chauves-souris peuvent constituer une source de protéines importante pour les populations villageoises pendant les périodes de soudure alimentaire mais en règle générale, il existe peu de données sur les valeurs socio-économiques ou culturelles des chauves-souris. Les chauves-souris frugivores ne produisent qu'un seul jeune par an, de sorte qu'elles sont sensibles à la pression de chasse bien que les grands dortoirs pourraient offrir l'occasion d'une exploitation gérée par la communauté pour assurer la sécurité des colonies et fournir une source de protéines mais de plus amples recherches sont nécessaires avant que cette alternative ne puisse être retenue. Les dortoirs constituent également les meilleures cibles des actions de protection de la nature et des efforts plus importants sont nécessaires pour contrôler la chasse en s'appuyant sur la législation nationale ainsi que sur des solutions locales plus souples et adaptées, basées sur la communauté. Les chauves-souris peuvent aussi transmettre des agents pathogènes et cette menace est une source d'inquiétude grandissante car de plus en plus d'espèces de chauves-souris ont été identifiées en tant que vecteurs de maladies virales émergentes.

KEYWORDS: bats, bushmeat, *Eidolon*, *Hipposideros*, hunting, *Pteropus*, *Rousettus*, roost

INTRODUCTION

Hunting of wildlife for food is a major threat to forest vertebrates in the tropics (Wilkie et al. 1998. Bakarr et al. 2001, Fa et al. 2002, Corlett 2007), but wild meat provides people with a vital source of protein and income (de Merode et al. 2004). Understanding the dynamics of bushmeat hunting, consumption and trade, especially the supply and demand of species that are of conservation concern, is a priority in areas where exploitation levels are high. For the more productive and abundant species, sustainable extraction may be possible, thus enabling local communities to use this resource for food and income (Robinson and Bennett 2004).

Most bushmeat studies in Africa have concentrated on central and western tropical forests on the mainland (e.g. Bakarr et al. 2001, Fa et al. 2005, Willcox and Namu 2007). By contrast, there are only a few accounts from the island of Madagascar, but there is evidence of an established hunting culture that points to regular consumption of terrestrial and flying vertebrates for food (Linton 1933). Wild animals that are hunted and consumed by people in Madagascar include lemurs, tenrecs, carnivores, bats, birds and reptiles (Randriamanalina et al. 2000, Garcia and Goodman 2003, Goodman and Raselimanana 2003, Goodman et al. 2004, Rakotondravony 2006).

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There are accounts of lemur hunting from Daraina in the north (Rakotondravony 2006), Parc National (PN) de Kirindy-Mite in the southwest, (Goodman and Raselimanana 2003), PN d'Ankarafantsika in the west (Garcia and Goodman 2003), Makira in the northeast (Golden 2005) and Fort Dauphin in the southeast (Randriamanalina et al. 2000). Lemurs are protected by Malagasy law but many species are hunted using baited traps, blowpipes, shot guns, catapults, dogs or spears.

Other frequently hunted mammals include tenrecs (Tenrecidae, Afrosoricida) and Bush pigs *Potamochoerus larvatus* (Goodman and Raselimanana 2003, Golden 2005, Rakotondravony 2006), and there is evidence that carnivores are also hunted and consumed in some areas, e.g. Makira (Golden 2005) and PN d'Ankarafantsika (Garcia and Goodman 2003). Reptiles are also eaten and although snakes are reportedly consumed (Rakotondravony 2006), the greatest demand is for tortoises and sea turtles (Garcia and Goodman 2003, Goodman and Raselimanana 2003, O'Brien et al. 2003, Goodman et al. 2004). Birds are also important bushmeat across the country (Garcia and Goodman 2003, Goodman et al. 2004, Rakotondravony 2006).

This review focuses on the hunting and human consumption of bats by people in Madagascar. As interest in the bats of Madagascar has increased in recent years significant advances have been made in understanding taxonomy, foraging and diet, and habitat use (Goodman and Ranivo 2004, Goodman et al. 2005, Andriafidison et al. 2006, Andrianaivoarivelo et al. 2006, Bates et al. 2006, Jenkins et al. 2007a, Picot et al. 2007). There are relatively few accounts of bats as bushmeat in Madagascar although the limited information available suggests that hunting levels of megachiropterans (MacKinnon et al. 2003), and at least one microchiropteran species (Goodman 2006), are high. The extent and frequency of bat hunting varies seasonally and geographically (MacKinnon et al. 2003) and not all hunting surveys have found evidence of bats as bushmeat (e.g. PN d'Ankarafantsika, Garcia and Goodman 2003; Mikea Forest, Goodman et al. 2004).

Madagascar now has close to 40 species of bats, 70 % of which are endemic (Racey et al. in press). They constitute a significant proportion of the island's mammalian diversity and play an important role as long-distance seed dispersers and pollinators (Bollen and van Elsacker 2002, Andriafidison et al. 2006, Picot et al. 2007). The three species of endemic Megachiroptera that occur on Madagascar were all considered to be threatened by hunting in the 2005 IUCN Global Mammal Assessment workshop in Antananarivo; *Pteropus rufus* and *Eidolon dupreanum* were classified as Vulnerable and *Rousettus madagascariensis* as Near-Threatened. There was little available information on the hunting of microchiropterans but the endemic insectivorous *Hipposideros commersoni* was also classified as Near-Threatened because of the reported impact of hunting.

In this review we collate data on bats as bushmeat, both published and unpublished, and report on general trends with respect to hunting methods, consumption patterns, conservation threats and human livelihood issues. We draw on personal experience in the field since 1998 (PAR) and 2002 (RKBJ) and have augmented the accounts by personal reports from our Malagasy colleagues engaged as either employees or students in successive projects organized by the University of Aberdeen and funded by the Darwin Initiative (1999-2005). Information on bat hunting was obtained through direct observations as well as informal discussions with people in a range of sites across the island (Figure 1).

FIGURE 1. Map of Madagascar showing the location of protected areas and towns names mentioned in the text and Table 1.

HUNTING BATS FOR MEAT The life history of bats is divided between the sites used for resting during the day ('roost') and the areas used at night for feeding. These two areas are often spatially distinct and can, for *Pteropus rufus*, be over 40 km apart (Racey et al. in press). People in Madagascar usually hunt bats either at roosting sites, where they aggregate, or at feeding sites where they forage in close proximity to human habitation (Table 1).

Fruit bats are very vulnerable to capture at night when they feed on fruits and flowers at low heights and close to villages. This type of exploitation is mainly for subsistence purposes and occurs in many areas of Madagascar. In the Menabe Region of western Madagascar local people use nets or natural hooks from plants such as *Uncarina grandidieri* (Pedaliaceae) to catch and snare foraging bats respectively (Figure 2). In southern Madagascar *Pteropus rufus* is netted when it feeds on sisal (*Agave sisalana*, Agavaceae) plants at night and at least some of the bats are sold locally (Rahaingodrahety 2007). Sometimes the need for obtaining bushmeat is secondary to protecting important fruit crops from the bats, as was reported by Andrianaivoarivelo et al. (2007) from Anosibe An'ala in the Alaotra Mangoro Region. Farmers in the Anosy Region also reported consumption of the bats killed during crop protection efforts (Rahaingodrahety 2007). Microchiropterans are hunted in small numbers away from their roost during foraging flights, especially when they are attracted to insect swarms around artificial lights or exceptionally when commuting bats are funneled into narrow spaces (Table 1).

TABLE 1. Summary of the species, methods and locations relating to bats as bushmeat in Madagascar. Personal communications refer to the following individuals (1: D. Andriafidison, 2: M. M. Picot, 3: H. J. Razafimanahaka, 4: A. Rabearivelo 5: F. H. Randrianandrianina, 6: C. Rahaingonirina, 7: A. R. Andrianaivoarivelo).

Type	Site	Bat Species	Period	Location	Methods	Source
Roosting	Cave	*Emballonura atrata*	Not known	Near Brickaville	Collection in sacks	Pers. Comm. (1)
Roosting	Rock crevice	*Eidolon dupreanum*	All year	East (Anosibe An'ala)	Ladder	Pers. Comm. (6)
Roosting	Rock crevice	*E. dupreanum*	All year	Widespread	Fire and sticks	Ranivo (2001)
Roosting	Rock crevice	*E. dupreanum*	All year	Highlands	Rope descent	P. A. Racey (Unpubl. data)
Roosting	Rock crevice	*E. dupreanum*	Oct.-Jul.	Highlands	Nets	Ranivo (2001)
Roosting	Rock crevice	*E. dupreanum*	Oct.-Jul.	Highlands	Collection in a sack	Ranivo (2001)
Feeding	*Eucalyptus* spp. flowers	*E. dupreanum*	Mar.-Apr.	Centre (near Fianarantsoa)	Nets	Pers. Comm. (2)
Feeding	*Ceiba pentandra* flowers	*E. dupreanum*	May-Jul.	West (Manja to Antsohihy)	Guns, nets, plant parts slingshots	Pers. Comm. (1)
Feeding	Feeding perch	*Hipposideros commersoni*	Jan.-Mar.	East (Tampolo)	Sticks	Pers. Comm. (3)
Roosting	Caves	*H. commersoni*	Jan.-Mar.	South (Itampolo)	Sticks	Goodman (2006)
Roosting	Foliage	*H. commersoni*	Feb.-May	West (Ankarafantsika)	Knocked from roost	Pers. Comm. (3)
Feeding	Ripe *Litchi chinensis*	Megachiroptera	Dec.	East (Anosibe An'ala)	Nets	Andrianaivoarivelo et al. 2007
Feeding	Ripe *Eugenia jambos*	Megachiroptera	Jan.-Mar.	East (Andilamena / Lac Alaotra)	Nets	Pers. Comm. (4)
Feeding	Commuting route	Microchiroptera	All year	West (Antsalova)	Sticks	R. K. B. Jenkins (Unpubl. data)
Roosting	Caves	*Miniopterus gleni*	Jan.-Mar.	South (Itampolo)	Sticks	Goodman (2006)
Roosting	Caves	*Miniopterus manavi*	Not known	East (Makira)		Golden (2005)
Roosting	Foliage (*Ravenala*)	*Myzopoda aurita*	All year	East (Tampolo)	Picked from inside plants	Pers. Comm. (3)
Feeding	*Ceiba pentandra* flowers	*Pteropus rufus*	May-Jul.	West (Manja to Antsohiy)	Guns, nets, plant parts, slingshots	Pers. Comm. (1)
Feeding	Sisal flowers	*P. rufus*	All year	Near Berenty Private Reserve	Nets	Rahaingodrahety 2007
Feeding	*Ficus* spp. fruit	*P. rufus*	All year	Widespread	Nets	Pers. Comm. (1)
Roosting	Emergence sites	*P. rufus*	All year	Widespread	Nets	Pers. Comm. (2)
Roosting	Roosting perch	*P. rufus*	All year	East (Moramanga)	Roost trees felled	Jenkins et al. 2007a
Roosting	Roosting perch	*P. rufus*	All year	Widespread	Guns	Pers. Comm. (1)
Roosting	Caves	*P. rufus*	Not known	East (Makira)	Not known	Golden (2005)
Roosting	Caves	*Rousettusmadagascariensis*	All year	East (Nosy Boraha,)	Sticks	Rakotondrasana and Goodman 2007
Feeding	Litchi trees	*R. madagascariensis*	Dec., Jan.	East (Anosibe An'ala)	Shotgun	Pers. Comm. (7)
Roosting	Caves	*R. madagascariensis*	All year	East (Anosibe An'ala)	Sticks	Pers. Comm. (6)
Roosting	Caves	*R. madagascariensis*	Oct.-Mar.	East (Tolagnaro)	Trap	Jenkins et al. 2007b
Roosting	Caves	*R. madagascariensis*	Not known	East (Makira)	Not known	Golden (2005)
Roosting	Caves	*Triaenops rufus*	Jan.-Mar.	South (Itampolo)	Sticks	Goodman (2006)

Many Malagasy bat species roost in some form of cavity, such as caves, fissures, roofs or tree holes (Racey et al. in press) and hunting occurs both inside the roosts and as the bats emerge or return (Table 1).

Rousettus madagascariensis is a small fruit bat (50-60g) that roosts in caves and although it is widespread, relatively few roosts have been discovered by biologists thus far (MacKinnon et al. 2003). Even though some roosts are protected from hunters because they occur in protected areas (Kofoky et al. 2007) or sacred sites (Rakotoarivelo and Randrianandrianina 2007), there are many reports of hunting in and around caves (Rakotondrasana and Goodman 2007, Jenkins et al. 2007b). A common method is to throw sticks at the roosting bats and collect the animals that fall, or strike them as they emerge from the cave (Rakotondrasana and Goodman 2007) before taking the animals back to the village (Figures 3 and 4). Goodman (2006) described the hunting method for *Hipposideros commersoni*, *Miniopterus gleni* and *Triaenops rufus* by villagers near Itampolo. Narrow

FIGURE 2. *Pteropus rufus* snared using hook-like plant burrs whilst feeding on kapok trees near Kirindy-Mite National Park (Photo: R. A. Andrianaivoarivelo)

FIGURE 3. Hunting *Rousettus madagascariensis* on Nosy Boraha: one man in the cave disturbs the bats by throwing sticks and his fellow hunters wait at the cave entrance to strike emerging bats (Photo: F. H. Randrianandrianina).

flyways were cleared in the vegetation surrounding the cave entrance and the bats were swatted with a wooden whip-like baton as they emerged (Figure 5).

Eidolon dupreanum and some molossids roost in fissures. *E. dupreanum* is a medium-sized megachiropteran (300 g) that is hunted for meat in many parts of Madagascar (Ranivo 2001, MacKinnon et al. 2003). Its roost sites are usually very high and located in cliffs and rock faces, making direct access by hunters difficult. Hunting is usually undertaken by specialists who either access roosts with wooden ladders or light fires directly underneath the roosts and net or swat flying bats as they emerge (Table 1). Alternatively, a hunter is lowered on a rope and hits the bats with a stick as they emerge (Table 1).

Only a few Malagasy bat species roost in foliage, notably *Pteropus rufus*, *Myzopoda aurita* and *Hipposideros commersoni*. The latter species roosts singly in trees at some sites but is difficult to locate during the day and we know of only one area where the bats are taken from trees and eaten. In PN d'Ankarafantsika local people collect a forest tuber (*Dioscorea maciba*, Dioscoreaceae) and occasionally encounter roosting *H. commersoni* which are taken back to the village and eaten (Table 1). In the area around Tampolo forest, people collecting leaves of the Travellers' palm (*Ravenala madagascariensis* Strelitziaceae) for housing materials often encounter *M. aurita* roosting in the unfurled leaves. Although there was no evidence that bats were deliberately sought, they were collected and taken back to the village where they were cooked and eaten. The Madagascar flying fox *P. rufus* is the island's largest bat (ca. 600 g) and roosts in the upper branches of large trees. It forms large (up to 5,000 individuals, MacKinnon et al. 2003), noisy colonies and is the main source of bat bushmeat in Madagascar. In many regions nets are erected inside or on the periphery (Figure 6) of roosts to intercept flying bats (Jenkins et al. 2007b). Firearms, notably shotguns, are also used to hunt *P. rufus* is many areas. In eastern Madagascar individual trees with roosting bats are felled by hunters who club the fallen animals with sticks (MacKinnon et al. 2003).

BATS AS BUSHMEAT There are few eye-witness accounts from biologists on the seasonality and frequency of hunting or the destination of the bat meat, and most reports are based

FIGURE 4. The results of a daily hunting trip to a cave roost of *Rousettus madagascariensis* on Nosy Boraha (Photo: F. H. Randrianandrianina).

FIGURE 5. A hunter near Itampolo poised at the 'mouth' of a ride cut in the forest from the cave to channel the emerging *Hipposideros commersoni* towards his long stick (Photo: H. J. Razafimanahaka).

FIGURE 6. Support poles for nets set permanently around the edge of a *Pteropus rufus* roost in western Madagascar (Photo: R. Randrianavelona).

on informal interviews (Rakotoarivelo and Randrianandrianina 2007, Rakotonandrasana and Goodman 2007) or brief observations (Goodman 2006). Quantitative information in particular is lacking and this prohibits a thorough assessment of sustainability. Nevertheless, it is possible to obtain an overview of the way in which bat bushmeat is traded and used in Madagascar.

Pteropus rufus is hunted in the Daraina area in northeastern Madagascar (Rakotondravony 2006) where roosts of over 1,000 animals have been reported from littoral forest. Although the people living around the roost refrain from eating the bats, the colonies are reportedly subject to frequent hunting by local immigrants (Rakotondravony 2006). In Makira, *P. rufus* is eaten widely by local communities and at $1.5 US / kg was the most expensive bushmeat and also exceeded the price of meat from most domesticated animals (Golden 2005). During July 2007 near Morondava, the price of *P. rufus* in restaurants exceeded beef, chicken and duck dishes, was the same as eel, and only tenrecs fetched a higher price (Figure 7). In the Mahavavy-Kinkony area of western Madagascar, regular hunting at a *P. rufus* roost was reported by Rakotoarivelo and Randrianandrianina (2007); hunting teams of up to eight men visited the roost on a regular basis and caught up to 100 bats on each occasion. These were sold around villages and to local restaurants for $0.5 US each. On Nosy Boraha, *P. rufus* is regularly exploited from at least one roost and is served seasonally in restaurants in the main town on the island (Rakotonandrasana and Goodman 2007). One hunter also reported that frozen shipments of *P. rufus* are sent to the mainland port of Toamasina (Rakotonandrasana and Goodman 2007). At a small restaurant near Mahajanga in 2000, at least 30 *P. rufus* were reportedly sold every day (Figure 8), although it is not clear whether this figure is a monthly average estimate or reflects a seasonal peak in availability (Racey et al. in press). In the sisal plantations surrounding Berenty Private Reserve, hunters can expect to catch 8-12 *P. rufus* per week between September and May and 25-30 between June and August. Bats are sold discretely in villages around the reserve for $0.7-1.0 US. Extrapolating these figures, a single hunter could catch between 164 and 192 bats per year (Rahaingodrahety 2007).

During a study on the diet of *Eidolon dupreanum* in the rainforest between PN de Ranomafana and PN d'Andringitra, a number of accounts on bat hunting were collected from villages (Picot 2005). Although familiar with the location of the bat roosts, the local people rarely hunted or consumed the bats. Professional hunters visited a few times a year and occasionally offered bat meat to the village but most of the animals were taken to larger towns and sold for $0.4 US each to restaurants and hotels. In this area the oil residue from cooked bats is used as medicine for whooping cough. Further north in the highlands, Ranivo (2001) investigated the hunting of *E. dupreanum* at roost sites near Ambositra, Antsirabe and Ankazobe. Villagers reported purchasing *E. dupreanum* directly from hunters between one and four times per year (Ranivo 2001).

The large fruit bats, *Pteropus rufus* and *Eidolon dupreanum*, appear to be the only species sold in restaurants. They are either served individually, complete with head and wings, jointed, or are diced up into small pieces and accompanied by rice (Figure 9). Small bats that are prepared in rural settings are often cooked together in large metal saucepans, whilst *Hipposideros commersoni* is either roasted over a fire or boiled (Figure 10). There is little evidence that people have distinct preferences for particular bat species and although larger species are usually the most sought after (explaining the prevalence of fruit bats and *H. commersoni* as bushmeat), there are accounts of people hunting the small (ca. 6 g) sheath-tailed *Emballonura* from caves in eastern Madagascar (Table 1).

THE IMPACT OF BAT HUNTING Rakotondravony (2006) considered hunting to represent a minor threat to *P. rufus* in the north of Madagascar, but noted that this species was frequently served in local restaurants. Other evidence suggests that, at last locally, current patterns of exploitation are unsustainable and this is obviously of concern to conservationists and those who depend on the bats for income and nutrition. Local

FIGURE 7. A menu in a roadside restaurant in western Madagascar during July 2007 showing the price of fruit bat *fanihy* as 2,000 ariary or $1 US. Other meats on the menu are *omby* (beef), *akoho* (chicken), *gana* (duck), *amalona* (eel) and *tandraky* (tenrec). (Photo: F. H. Randrianandrianina).


FIGURE 8


FIGURE 9


FIGURE 10

FIGURE 8. *Pteropus rufus* in a cage in the kitchen of a small roadside restaurant in western Madagascar (Photo: J. L. MacKinnon).

FIGURE 9. Fruit bat served in a home in western Madagascar (Photo: F. H. Randrianandrianina).

FIGURE 10. *Hipposideros commersoni* being cooked in a small village in western Madagascar (Photo: H. J. Razafimanahaka).

extirpation would also result in a loss of the important ecological services provided by fruit bats.

Ranivo (2001) found that hunting *Eidolon dupreanum* caused the bats to abandon traditional roost sites and local people noted declines in hunting returns. Golden (2005) reported that the large annual harvests of *Rousettus madagascariensis* and *Pteropus rufus* in the Makira forest and Maroantsetra were unsustainable and Goodman (2006) concluded that harvest level of *Hipposideros commersoni* (ca. 70,000-140,000 bats annually) surpasses the likely productivity of the species in the area. Furthermore, simple extrapolation of the reported 30 bats per day served in a restaurant in the west (Racey et al. in press) results in over 10,000 bats served per year, a number that suggests a large catchment area and the presence of dedicated hunting teams. Hunting for *H. commersoni* at the Mitoho Cave in PN de Tsimanampetsotsa may have been the reason for this species to abandon the site (Goodman et al. 2002). Furthermore, high desertion rates of *E. dupreanum* and *P. rufus* in the central highlands was attributed to over-hunting (MacKinnon et al. 2003). There is therefore growing evidence that hunting is threatening the existence of fruit bat roosts across Madagascar although it should be noted that there are probably examples of low level subsistence hunting that continues at a sustainable level.

BAT BUSHMEAT AND HUMAN LIVELIHOODS There are few accounts of the relationship between bat bushmeat and human livelihoods in Madagascar. In general, bats appear to contribute either to the livelihoods of hunters who collect bats to order, to sustain the demand from restaurants, or are important as a subsistence food that provides protein for the hunter and local village. Goodman (2006) reported that the harvest of *Hipposideros commersoni* in the south occurred when the bats had accumulated fat deposits and people were experiencing food shortages. If this scenario is representative of other areas of Madagascar then the bat meat may be a crucial dietary component for people living with low food security.

There is growing evidence that bats harbor diseases that may infect humans (Messenger et al. 2003, Breed et al. 2006). In a preliminary study on Malagasy fruit bats antibodies to Henipa and Tioman Virus were found in a small number of samples suggesting that these viruses have been present (Iehlé et al. 2006). In addition to eating bats, humans also eat fruit that has been in contact with bats and in some areas large roosts of microchiropterans occupy the roof spaces of schools and hospitals. More information is now needed on the risk of pathogen transmission to humans from eating bat meat or through direct contact with bat feces and urine because any assessment of the positive livelihood contribution from bats needs to consider the potential impact to human health.

DISCUSSION

Bats are hunted and consumed by people throughout Madagascar but the economic importance of the meat, the hunting industry, and its impact on the survival of bat populations remain poorly understood. Whilst it is possible that some traditional methods of harvesting bats are sustainable there are increasing reports of the collection of large, and presumably unsustainable, numbers of bats. In other islands traditional, low-level and presumably sustainable, flying fox harvests have been replaced by chronic over-hunting associated with the proliferation of firearms (Brooke and Tschapka 2002, Monson et al. 2003). Firearms are used in Madagascar and elsewhere to hunt bats but shotguns and ammunition are relatively expensive and are not yet widely used; most hunting is still carried out using nets, sticks and traps.

The value of bat bushmeat to individuals and communities has yet to be established in Madagascar but mammals in mainland Africa provide a vital source of protein and income for rural communities, with the importance of bushmeat to households varying according to family wealth and season (de Merode et al. 2004). Bushmeat hunting is also thought to lead to a decrease in population size and a concomitant decline in ecosystem function through the loss of seed dispersers, grazers and browsers (Corlett 2007). Malagasy fruit bats play an important role in seed dispersal and pollination and the maintenance of these services requires healthy bat populations. There are therefore compelling reasons to conserve bats in Madagascar but also to allow some level of hunting because of the traditional and socioeconomic value of the meat. Balancing these factors is a major challenge for conservationists.

In mainland Africa, forest antelopes and primates contribute most biomass to bushmeat (de Merode et al. 2004) and bats are much less frequently encountered (e.g. Wilcox and Nambu 2007). Fa et al. (2006) found that bats (*Eidolon helvum*) had one of the lowest extraction levels of over 50 forest mammals in Nigeria and Cameroon. However, colonies of roosting bats are not necessarily associated with tropical forests (Halstead 1977, Mickleburgh et al. 1992) and there is evidence of bat hunting from more urban settings (Funmilayo 1976, 1978). Comparisons with tropical Asia are also relevant given the distribution of pteropodid bats. Lee et al. (2005) found that large pteropodid

bats were one of the most commonly traded wild meats on north Sulawesi and the demand was high enough to result in the probable extirpation of colonies. On Indonesian Borneo, *Pteropus vampyrus natunae* is hunted at feeding sites to supply the provincial demand for bat meat (Struebig et al. 2007). *Pteropus* bats occur on many of the small islands in the Indo-Pacific Region and continue to be an important traditional source of food but over-hunting is thought to be the cause of population declines in many species (Heaney and Heideman 1987, Mickleburgh et al. 1992, Craig et al. 1994, Bowen-Jones et al. 1997, Wiles et al. 1997, Brooke and Tschapka 2002).

Malagasy bats are classed as game under Malagasy law and there are two defined hunting seasons, one for fruit bats and the other for *Hipposideros commersoni* (Durbin 2007). However, the seasonality of bat hunting appears to depend mostly on the availability of the bats rather than the legal hunting season. The ephemeral nature of fruit and flowers means that hunters can only trap foraging bats at certain times of the year, which can, as in the case of kapok (*Ceiba pentandra* Malvaceae), coincide with the hunting season. The period when litchis (*Litchi chinensis* Sapindaceae) are ripe (November to January) affords the opportunity for hunters to trap fruit bats outside of the open season (1 May-1 September for all fruit bats). *H. commersoni* in the south is hunted between December and March, a period that partially coincides with the hunting season for this species (1 February-1 May). It is therefore important to establish that, even though bat hunting is reported to cause roost desertions and is locally unsustainable (Golden 2005, Goodman 2006, Racey et al. in press) there is only a very weak legal framework which conservationists can use to control bat hunting. In some areas hunters are reported to release pregnant females or to refrain from hunting during the period of pregnancy. This type of management is based on local knowledge of bat biology and does not correspond to the legal hunting season because most bat species in Madagascar are pregnant between August and December. The bat roosts that are located in Madagascar's network of parks and nature reserves receive full protection from hunting and the creation of new protected areas offers the opportunity to conserve important roosts. However, some species like *Pteropus rufus* appear rather rare in the existing system of protected areas (MacKinnon et al. 2003) and because illegal hunting in parks is known to occur (Garcia and Goodman 2003, Cardiff 2006), management teams should regularly monitor important bat roosts to deter hunting.

Culture and tradition play an important role in determining patterns of bushmeat exploitation. Taste preferences vary according to region and ethnic group and account for some of the variation in the consumption of bat meat across Madagascar (MacKinnon et al. 2003). Some bat roosts receive total protection from hunters because they are located in sacred burial sites (Rahaingodrahety 2007, Rakotoarivelo and Randrianandrianina 2007).

The large size of Madagascar and the geographical distribution of bat roosts prohibit a well organized annual hunt of the type reported from small oceanic islands (Brooke and Tschapka 2002). Managed harvests may work best if the local traditions are taken into account which in Madagascar would require regional flexibility in the timing and duration of hunting periods. Given the variability of fruiting seasons for many plant taxa, studies should be carried out in several regions before these measures can be considered. Any recommendations on how to reconcile hunting and bat conservation need also to be based on regional assessments of the bushmeat trade, and such data are currently lacking. Long-term information on population change and roost occupancy is also needed because any impact of hunting may be exacerbated by the loss of roosts to agricultural expansion.

Conservationists recognize the importance of bushmeat to rural livelihoods and this is manifest in the quest for sustainable harvests to maintain wildlife populations and support human populations. There are a number of publications about sustainably harvesting terrestrial mammals (Fitzgibbon et al. 1995, Wilkie et al. 1998, Robinson and Bennett 2004) but very few on bats, an exception being Halstead (1977). Some of the data, such as carrying capacity, that are required to make assessments of sustainability using classical methods are difficult to obtain for bats. Nevertheless, Vardon and Tidemann (1995) suggested that a sustainable harvest of Australian *Pteropus* fruit bats could reduce the demand for declining and threatened *Pteropus* from the Pacific Islands.

In Madagascar sustainability could be achieved through cooperation with local communities, government and scientists. Initial assessments would necessitate field studies on population size and turnover as well as detailed recording of harvests. Management options include charging visiting hunters, implementing a closed season or prohibiting the use of firearms. Each of these will depend on the particular socioeconomic and cultural conditions in the area of the roost. Hunting bats at their feeding sites is probably less of a conservation threat if roosts are protected and offers a compromise between consuming and conserving bats.

There are a number of research and conservation priorities which, if addressed, could assist in the more robust assessment of the impact of hunting and the role of bats as bushmeat. They could also lead towards viable community-driven conservation management plans and a reduction in local extirpations.

ECOLOGICAL DATA There are few data on the breeding biology and roosting ecology of bats in Madagascar. New information on roost location, dispersal patterns, productivity, and population size is therefore needed.

DISEASE TRANSFER A more thorough virological survey is needed of the bat species that are most commonly consumed by people to assess possible human health risks from eating bats.

HARVESTING AND TRADE In conjunction with ecological information, data are needed on the dynamics of the bushmeat trade and harvesting patterns. In particular, seasonal and regional variation in the commercial aspects of bat bushmeat is required.

CULTURAL ISSUES Aside from the ecological and economic issues, it is important to determine the influence of culture and tradition. This should address taste preferences, taboos and non-food uses of bats.

ROOST CONSERVATION Roosts sites need protection from hunting, habitat loss (e.g. conversion to farm land) and other disturbances (e.g. people visiting caves). Important roosts in each of Madagascar's regions should be identified and conservation plans proposed.

SUPPORTING COMMUNITIES Local institutions need regular support to monitor and conserve bat roosts, especially in sites subject to heavy exploitation from outsiders.

Sustainable bat conservation is possible in the long term in Madagascar, if major issues are addressed, such as the implementation of conservative harvests, providing communities with greater control over exploitation by visiting hunters, and creating a network of roosts that are protected from all forms of hunting.

ACKNOWLEDGEMENTS

This manuscript followed from a series of stimulating discussions with Marcus Rowcliffe and Julia Jones about bats and bushmeat in Madagascar. Some of the data reviewed here were presented at a UEA Madagascar Symposium in March 2007. This review would have been impossible without the contributions of our co-workers in Madagasikara Voakajy and its partner organizations: D. Andriafidison, R. A. Andrianaivoarivelo, A. Rabearivelo, V. H. Rahaingodrahety, C. Rahaingonirina, I. M. O. Raharinantenaina, S. Raharimbola, A. Rakotoarivelo, M. Ralisata, T. Ramihangihajason, R. Rampilamanana, F. H. Randrianandrianina, N. Razafindrakoto and H. J. Razafimanahaka. We also thank: C. Hawkins, A. F. Kofoky, E. Long, T. Mbohoahy, M. Raheriarisena, J. Ranivo and F. H. Ratrimomanarivo. We would also like to thank the following people for supporting our conservation work: C. Andrianarivo, R. Brett, B. Donaldson, A. F. A. Hawkins, J. L. MacKinnon, J.-P. Paddack, D. Rakotondravony, J.-B. Ramanamanjato, O. R. Ramilijaona, V. Raminoarisoa, N. Raminosoa, N. Ratsifandrihamanana, J. Ratsirarson, J. Ratsimbazafy, H. Ravelomanantsoa, E. Razafimahatratra, F. Rejo-Fienena, M. Vincelette and A. Walsh. We are very grateful to the Malagasy government for giving us permission to undertake our work, which was done in collaboration with the Association Nationale pour la Gestion des Aires Protégées, the Département de Biologie Animale, Université d'Antananarivo, the Département de Biologie, Université de Toliara and the Département des Eaux et Forêts, Ecole Supérieure des Sciences Agronomiques, Université d'Antananarivo. Félicien Randrianandrianina prepared Figure 1. RKBJ was funded by the Darwin Initiative and we would also like to thank, BP Conservation Leadership Programme, Bat Conservation International, British Ecological Society, Cleveland Metroparks Zoo, Conservation International, Disney Wildlife Conservation Fund, Fauna and Flora International, Lubee Bat Conservancy, National Geographic Society, Peoples' Trust for Endangered Species, Rufford Small Grants, WWF Prince Bernhard Scholarship and the Wildlife Conservation Society for supporting our various bat conservation projects. An anonymous referee provided helpful comments on the first submission.

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Discovery of *Macrotarsomys bastardi* at Beza Mahafaly Special Reserve, southwest Madagascar, with observations on the dynamics of small mammal interactions

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ABSTRACT

We report the presence of *Macrotarsomys bastardi*, Bastard's big-footed mouse, at the Beza Mahafaly Special Reserve in southwestern Madagascar. Despite years of fieldwork, including field research targeting the nocturnal mammals, this species had never been reported here previously. A program of intensive and random capture of nocturnal mammals was established over a period of one year (October 2006 to September 2007). We monitored the relative abundances and microhabitat preferences of small-bodied nocturnal mammals in three forests at Beza, as reflected in trapping success both on the ground and at heights of one to two meters in the trees. Three species are common at Beza (although they have different apparent habitat preferences): *Microcebus griseorufus*, *Rattus rattus*, and *Echinops telfairi*. Endemic rodents appear to be rare. Possible interactions between introduced rodents (rats and mice) and endemic species of rodents (*Macrotarsomys* and *Eliurus*) are also discussed.

RÉSUMÉ

Après plusieurs années de recherches dans la Réserve Spéciale de Bezà Mahafaly au Sud-ouest de Madagascar, y compris les recherches sur les mammifères nocturnes, la présence de *Macrotarsomys bastardi* (famille des Nesomyidae) est signalée pour la première fois dans cet endroit. Une série d'échantillonnage et une séance de capture intensive des espèces nocturnes ont été organisées durant une année dans trois forêts différentes de cette région (entre octobre 2006 et septembre 2007). Les pièges avaient été installés sur le sol ou sur des branches à une hauteur comprise entre un et deux mètre(s) pour évaluer l'abondance relative et la préférence pour des microhabitats des micromammifères nocturnes. Trois espèces, ayant chacune des préférences particulières pour un type d'habitat, sont fréquentes à Bezà Mahafaly, à savoir *Microcebus griseorufus*, *Rattus rattus* et *Echinops telfairi*. Les rongeurs endémiques sont rares (*Macrotarsomys* et *Eliurus*), fait qui pourrait s'expliquer par leur interaction avec les rongeurs introduits (rats et souris) qui est discuté ici.

KEYWORDS: *Macrotarsomys bastardi*, Beza Mahafaly, Rodentia, *Eliurus myoxinus*, Nesomyidae

INTRODUCTION

Three species of rodents, including two introduced species (*Rattus rattus* and *Mus musculus*, superfamily Muroidea, family Muridae) and one endemic species (*Eliurus myoxinus*, superfamily Muroidea, family Nesomyidae) have been previously reported at Beza Mahafaly Special Reserve (BMSR) in southwestern Madagascar (S23°41'20", E44°34'20") (Ratsirarson et al. 2001, Ratsirarson 2003). We report for the first time the presence in the reserve of a second endemic rodent, *Macrotarsomys bastardi*, Bastard's big-footed mouse (family Nesomyidae).

This species was previously recorded at a number of localities in southwestern Madagascar not far from Beza Mahafaly but never in the reserve itself. Its published distribution includes Sept Lacs along the Onilahy River, Toliara (north of Beza Mahafaly, see Rasoma and Goodman 2007) and north of the Onilahy River, in the regions of St. Augustin and along the Fiherenana River (Route Nationale 7, regions of Zombitse and Isalo; Carleton and Schmidt 1990, Jansa et al. 2008). It also occurs in both primary and degraded forests in the central highlands, southeast of the Mangoky, in the regions of Ihosy and Midongy (Rakotondravony 1996). It has been captured at Tsimanampetsotsa National Park, which is located to the southwest of Beza Mahafaly (Goodman et al. 2002). Indeed, the species is distributed along the southern and western coasts of Madagascar, from the region of Fort Dauphin (in the southeast) to the region of the Sofia River (Belambo) in the northwest (Garbutt 2007, Jansa et al. 2008).

Given this broad geographic distribution, this species has been accorded a 'low risk' conservation status (IUCN 2008) However, its survival at particular localities may be threatened due to human-induced environmental change or to the possible effects of introduced rodents (especially *Rattus rattus*), and it is imperative that interactions between humans, endemic rodents, and rats are better understood. During the year October 2006-September 2007, we captured rodents (murids and nesomyids), tenrecs (*Echinops telfairi*), and primates (*Microcebus griseorufus*) in several forests at Beza Mahafaly (including protected and unprotected habitats). This was the first intensive effort to document the populations of rodents at this site. Beza Mahafaly was established as a protected area in 1986 (Ratsirarson et al. 2001).

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METHODS

Beza Mahafaly is ecologically diverse, with a 90 ha Parcel 1 comprised partially of gallery forest and bordered along its eastern limit by a small river (the Sakamena, which is dry for around seven months every year). There is also a 520 ha spiny forest (Parcel 2) approximately 10 km to the west of Parcel 1 (Ratsirarson et al. 2001). Both parcels belong to the reserve, but only Parcel 1 has been fenced. Parcel 1 is considerably smaller in size than Parcel 2, and it is located near the main research camp. The fence was erected to keep cattle from entering this part of the reserve. The two are connected by a transitional dry forest corridor. Another dry forest is located near a village, Ihazoara, just southeast of Parcel 1, but that forest is not part of the reserve. Within a distance of around 20 kilometers from Parcels 1 and 2 are situated 17 villages with a combined human population of over 5,700 individuals (ca. 60% children) (unpublished records of the Commune Rurale Ankazombalala). According to the records of the Beza Mahafaly research station (the camp site, located just to the south of Parcel 1), the reserve attracts around 70 tourists and 30 researchers annually. Figure 1 shows a schematic map of the Reserve (Parcels 1 and 2) and several of the nearby villages, including Ihazoara. The forest at Ihazoara is located to the east and south of the village.

Trapping occurred on a regular basis between 9 October 2006 and 30 September 2007. All captures were conducted at night, when these animals are active. Four months were scheduled for intensive sampling (October, January, May, and September) and all other months were scheduled for random sampling. This schedule was established to best sample individuals at very different times during the year, including the beginning of the wet season (October) and the middle of the wet season (January), the middle of the dry season (May), and the end of the dry season (September). During the periods of intensive sampling, we set 180 Sherman traps every night at each of three forests at Beza Mahafaly, Parcel 1 (gallery, protected), Parcel 2 (spiny, protected) and Ihazoara (dry, unprotected). The trapping in October extended until November 8, so each period of intensive capture encompassed 30 days. Sherman traps are made of aluminum (7.7 cm x 7.7 cm x 30.5 cm) with a spring-operated front door. All trapping locations were flagged and their positions recorded using GPS. During the months of intensive capture, the traps were set on every day of every week in grids measuring 275 m x 225 m. They were set at distances 25 meters apart; 60 trees had only one trap set at heights of one to two meters, 30 had two traps set in the tree (one at ca. one meter and a second at ca. two meters height), and 30 had a single trap set in the tree (again at between one and two meters) and a second trap set on the ground near the tree's base. The total number of traps set each night at each forest location was 180, equaling 5,400 trap-nights per month of intensive capture at each location. Traps were baited with banana at 1730h and checked at 0500-0600h in the morning. When they were occupied, the animals were brought to the camp for measurement (weight, head length, body length, tail length, total foot length, and ear length), and for the collection of biological samples (blood, fur, ear tissue, feces, external parasites). To facilitate the collection of morphometric data and the marking procedure (cutting small pieces of ear tissue), individuals were temporarily anesthetized using appropriate dosages of Telazol® (which combines the anesthetic drug tiletamine HCl with the benzodiazepine anxiolytic drug, zolazepam HCl). All individuals were released in the afternoon or early evening at the site of capture.

During the eight months slotted for random sampling, five smaller grids (each measuring approximately 20 x 20 m^2) were set at randomly selected places within each of the three forests. Nine traps were set in each of the five grids at heights of one to two meters (spaced ca. 10 m apart) and three additional traps were set on the ground. Trapping occurred for five days per week for three consecutive weeks (for a total of 900 traps per forest per month). Trapping locations were flagged and their positions recorded using GPS. The above procedures were followed whenever individuals were found in the traps. At the end of each of the eight months devoted to random sampling, we conducted intensive sampling following

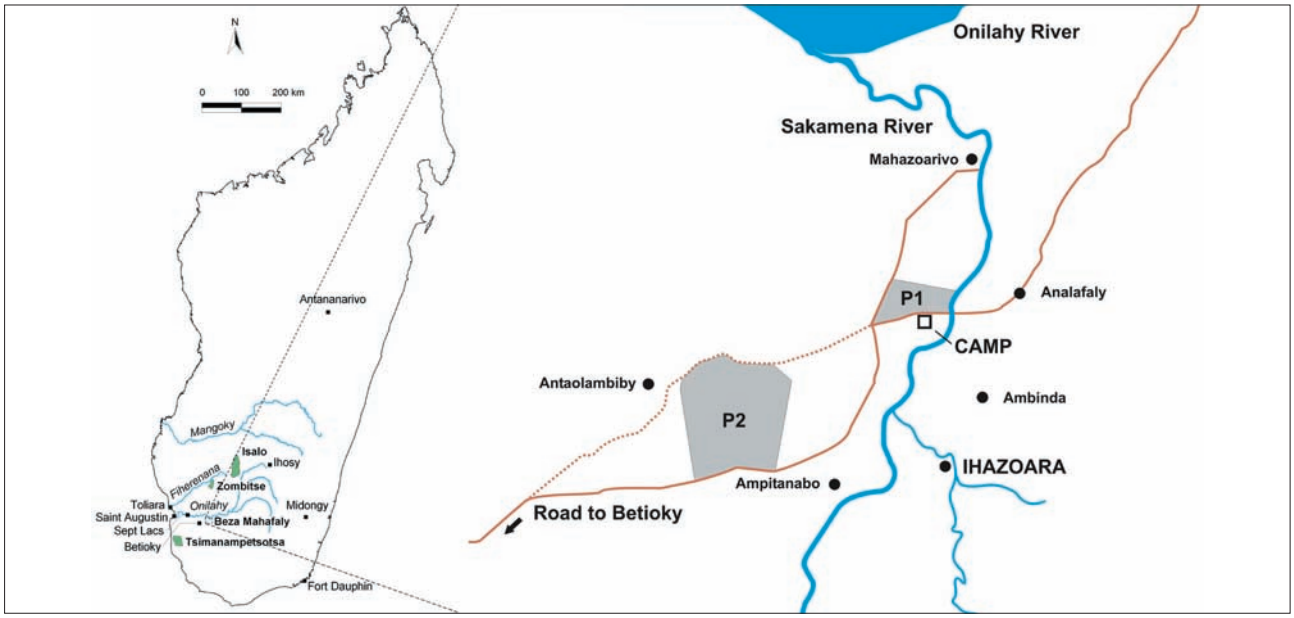

FIGURE 1. Map of Beza Mahafaly showing the locations of Parcel 1, Parcel 2, Ihazoara village (with forest to the south of the village) and other nearby villages.

the procedures laid out above over a three day period in the standard sampling grid, for an additional total of 180 x 3 traps per forest site per month.

In total, we set 33,120 traps in each of the three forests (or 99,360 traps in all three forests) over the entire year. There were two months of intensive capture (October and January) in the 'wet season' and two (May and September) in the 'dry season' plus eight months of random capture (four in each season). To make the data comparable across months, we converted numbers of individuals captured to capture success rates, taking into account the number of traps set in each month.

Simultaneously, 20 traps were set each night at three villages – Mahazoarivo north of Parcel 1, Ampitanabo south-east of Parcel 2, and Ihazoara northwest of the Ihazoara Forest (Figure 1). An additional 20 traps were set each night at the research campsite adjacent to Parcel 1. These traps were placed randomly within the villages and the camp. They were checked in the morning and trapped animals were brought to the camp-site for measurement.

All precautions were followed to help prevent the spread of disease. For example, occupied traps were cleaned with soap and water before being reused for the following night's trapping. Animal handlers wore gloves when handling the animals. If traps were empty, their doors were closed and the banana bait was discarded.

RESULTS

Among the rodents captured were two endemic species *Macrotarsomys bastardi* (n = 3) and *Eliurus myoxinus* (n = 1), numbers that pale in comparison to the numbers of *Rattus rattus* and *Mus musculus* simultaneously captured not only in areas of human occupation, but also in gallery forest. The endemic rodents were trapped only in Parcel 1 (gallery forest), and never in any of the villages or in the two drier forest habitats. The total number of endemic rodents trapped during the entire year in the three study forests represents less than 5 % of the total number of introduced rodents that entered the traps. In total (excluding recaptured individuals), we captured 254 *Microcebus griseorufus*, 59 *Rattus rattus*, 46 *Echinops telfairi*, 32 *Mus musculus*, 1 *Eliurus myoxinus*, and 3 *Macrotarsomys bastardi*.

Many more rats and mice were captured at the three villages (generally between one and two per night at each site), but no endemic species (*Microcebus griseorufus*, *Echinops telfairi*, *Eliurus myoxinus*, or *Macrotarsomys bastardi*) were ever captured within the boundaries of the three villages. At the camp proper, rats were captured approximately every other day. Rats entered the kitchen and the camping area (where researchers and tourists set up their tents); no other species were captured in traps set within the camp. In July 2005 a pair of *Microcebus* was captured in a trap set in a *Sasavy* tree (*Salvadora angustifolia*, Salvadoraceae) near the outdoor kitchen; this pair was observed in the same tree during the year 2006-2007, but did not enter any of the traps set in the camp.

Within the forests proper, mouse lemurs entered traps repeatedly. Of 254 mouse lemurs captured during the year, 70 (27.7 %) were captured twice or more. Of the 59 *Rattus rattus* captured in forests during the year, 24 (40.7 %) were recaptured. None of the individuals of the other species were recaptured. Here we limit comparisons to data on the number of first captures by location and month (Table 1).

TABLE 1. Total captures, by forest, month, and species. Dark coloured months represent intensive capture schedules. For each of these months at each site, 5,400 traps were set. For (un-bolded) random capture months, 1,440 traps were set at each site.

A. Parcel 1 captures per month per species

Genus	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Rattus	12	6	3	0	0	0	2	1	8	10	6	4
Mus	2	1	0	0	0	0	0	3	1	1	2	3
Eliurus	0	0	0	0	0	0	0	0	1	0	0	0
Macrotarsomys	0	0	0	0	0	0	0	1	2	0	0	0
Echinops	2	1	5	3	4	1	0	0	0	0	0	0
Microcebus	10	0	3	13	0	0	2	38	16	26	6	4

B. Parcel 2 captures per month per species

Genus	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Rattus	0	0	0	0	0	0	0	0	1	0	1	0
Mus	0	0	0	0	0	0	0	0	0	0	0	0
Eliurus	0	0	0	0	0	0	0	0	0	0	0	0
Macrotarsomys	0	0	0	0	0	0	0	0	0	0	0	0
Echinops	0	1	5	2	7	4	1	1	0	0	0	0
Microcebus	10	3	1	1	0	1	1	35	4	4	8	2

C. Ihazoara captures per month per species

Genus	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Rattus	1	1	0	0	0	0	0	1	0	2	0	0
Mus	3	4	1	2	0	0	0	0	1	1	3	4
Eliurus	0	0	0	0	0	0	0	0	0	0	0	0
Macrotarsomys	0	0	0	0	0	0	0	0	0	0	0	0
Echinops	1	2	1	3	0	0	0	0	0	0	0	0
Microcebus	5	1	1	2	2	3	8	15	9	4	6	1

Figure 2 shows a breakdown of capture success for the three most frequently trapped species by forest and month. Individual species showed strikingly different capture patterns across months, and sometimes by location. *Rattus rattus* was significantly more prevalent within Parcel 1 than at either of the other forests (ANOVA of capture success / month by location for rats only: $F = 9.4$, df (2, 33), $p = 0.001$). *Rattus* was not captured at any forest during the wettest months (January through March) when food at all sites was abundant. In contrast, *Echinops* was captured most often in the spiny forest, but not at all during the months of June through September, when it hibernates. *Microcebus* tended to be captured in relatively high numbers at all three forests (with no significant difference in capture success, but with the highest mean success rate in the gallery forest). They were captured throughout the year, but least often during the months of February and March (again during the wet season, when food was abundant). Neither females nor males enter seasonal torpor (as occurs in certain other cheirogaleid species; Schmid and Kappeler 1998, Atsalis 1999 and 2008, Rasoazanabary 2006), so both males and females were frequently captured during the dry season (April through

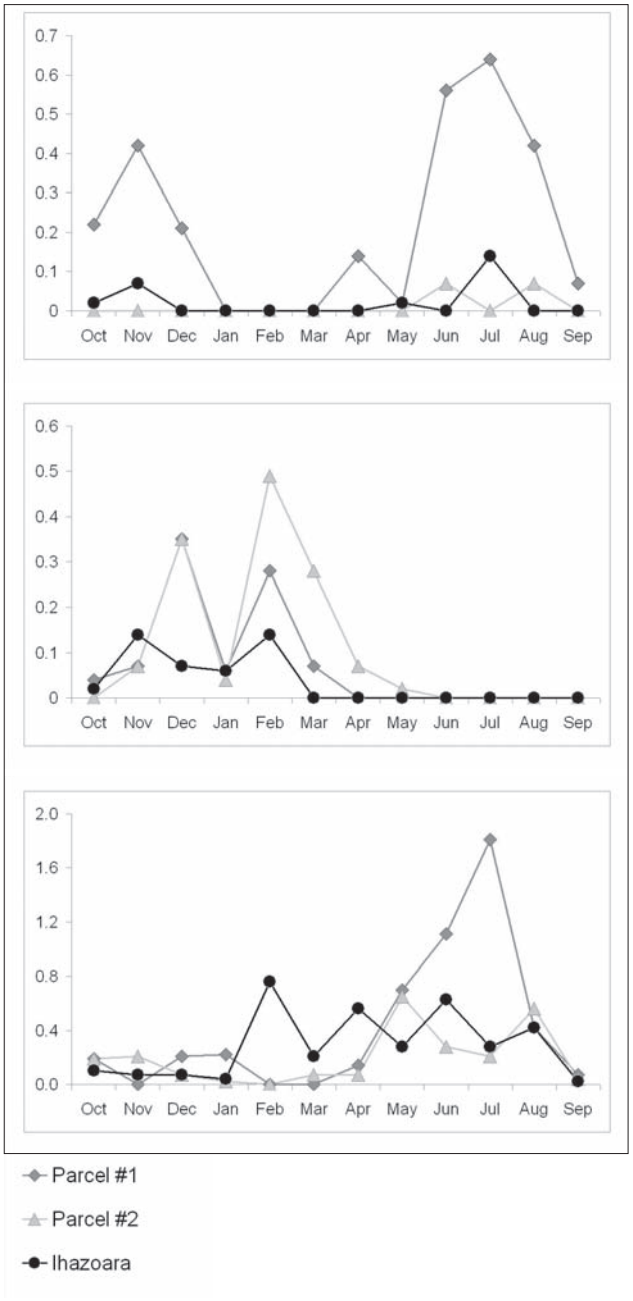

FIGURE 2. Capture success (%) by month at three forest locations for the three most abundant species: *Rattus rattus* (top graph), *Echinops telfairi*, *Microcebus griseorufus* (bottom graph).

September). The abundance of *M. griseorufus* in the gallery forest was unexpected, as this species of mouse lemur is found only in spiny forests at Berenty in southern Madagascar while another species of *Microcebus* (*M. murinus*) inhabits the gallery forest (e.g. Yoder et al. 2002). There is no evidence of the presence of *M. murinus* at Beza Mahafaly (Heckman et al. 2006), and *M. griseorufus* also occurs in the gallery forest.

Less frequently captured were *Mus*, *Eliurus*, and *Macrotarsomys*; *Mus musculus* was never found in the spiny forest, but it was captured at Ihazoara forest and, somewhat less frequently, in Parcel 1. *Macrotarsomys bastardi* was captured only at the gallery forest (Parcel 1) and only during the months of May (one female) and June (one male and one female). *Eliurus myoxinus* was also captured in the gallery forest during the month of June (one juvenile male).

Species differed significantly in their capture totals in both the 'dry' season [April to September, ANOVA $F = 11.2$, df (5, 12), $p < 0.001$], and the 'wet' season [October to March, ANOVA $F = 6.3$, df (5, 12), $p = 0.004$] with mouse lemurs showing high capture frequencies at all locations, and the two endemic rodent species showing low capture frequencies at all locations (indeed, no captures in Parcel 2 or Ihazoara regardless of season).

Table 2 shows the frequencies of successful trapping on the ground as opposed to 1-2 m above the ground, by species and site. During the months of intensive capture, because 150 traps were set in the trees and 30 on the ground, the expected capture success rate, if indeed there was no preference for ground vs. trees, is 5:1 (trees : ground). During all other months, the ratio of traps set in the trees to on the ground was 3 : 1.

It was not surprising that mouse lemurs (*Microcebus griseorufus*, which are highly arboreal) were most frequently trapped above the ground. However, it is also interesting that mouse lemurs were trapped regularly (19.8 % of all captures) on the ground. Ground captures for mouse lemurs were most frequent during the dry season. Behavioral observations of radio-collared mouse lemurs by one of the authors (ER, unpublished data) demonstrated a tendency of mouse lemurs at Beza to descend to the ground, especially in protected forests. This behavior was observed in association with feeding on insects and drinking water, both in the gallery and spiny forests. Rats were captured in ratios of 3 : 2 (36 captures in the trees to 23 on the ground). Introduced rats appear to be invading arboreal niches in the forests of Madagascar, at least at Beza Mahafaly. In contrast, 78.1 % of *Mus musculus* captures were in traps located on the ground. All captures of the endemic rodents, *Macrotarsomys bastardi* and *Eliurus myoxinus*, were on the ground, as were all captures of the tenrec *Echinops telfairi*. According to behavioral observations made by Salton (2005), *Echinops telfairi* is one of the more arboreal of tenrecoids (see also Salton and Szalay 2004, Salton and Sargis 2008), and it is therefore perhaps surprising that none of its captures were above the ground. Salton (2005) regularly observed *Echinops* at Beza Mahafaly in the trees, between one and two meters off the ground. However, like other tenrecoids, *Echinops* do spend a fair amount of time on the ground, and they can be found resting under logs and sometimes hibernating under tree roots in holes in the ground (Salton 2005, IAJY pers. obs.).

Morphometric data collected for *Macrotarsomys bastardi* and the other small-bodied mammals at Beza Mahafaly are provided in Table 3. This species is about twice as large as *Mus musculus* but only one fifth the size of sympatric *Rattus rattus*. As expected of *Macrotarsomys bastardi*, the head is relatively large, and the tail is relatively long (approximately one third longer than the combined length of the head and body). The ears and feet are relatively large. Ear length averaged 17.7 mm. The hindfoot is 80 % as long as the head. The dorsal coat is gray-brown (less brown and more gray than in *Rattus*); the ventrum is whitish and has less of a yellow hue than that of sympatric *Rattus*. The tail matches the color of the dorsal fur but is somewhat darker; it lacks the distinctive hairy tuft present on the tails of *Eliurus*. Specific dimensions closely match those of *Macrotarsomys bastardi* from other sites (Goodman et al. 2006). Our three individuals varied in weight from 18 to 23 g; Carleton and Goodman (2003) and Goodman et al. (2006) report a weight range of 21-28 g for adult *M. bastardi*; the mean adult mass is 24.5 g.

TABLE 2. Frequency of successful 'trapping on the ground' versus '1-2 meters above the ground', grouped by species and site.

Genus	Parcel 1 (ground)	Parcel 1 (tree)	Parcel 2 (ground)	Parcel 2 (tree)	Ihazoara (ground)	Ihazoara (tree)
Rattus	21	31	0	2	2	3
Mus	11	2	0	0	14	5
Eliurus	1	0	0	0	0	0
Macrotarsomys	3	0	0	0	0	0
Echinops	16	0	21	0	9	0
Microcebus	29	89	9	61	12	54

TABLE 3. Morphometric data of nocturnal mammals at Beza Mahafaly, excluding infants and juveniles except where noted (N, mean, and, in parentheses, standard deviation)

Genus and species	N	Body mass (g)	Head length (mm)	Body length (mm)	Tail length (mm)	Foot length (mm)	Ear length (mm)
Rattus	49	106 (17.6)	45.4 (3.5)	113.1 (13.7)	117.2 (25.9)	31.6 (2.5)	21.5 (1.3)
Mus	30	11.7 (1.9)	24.7 (1.4)	50.3 (6.7)	70.7 (6.1)	15.3 (1.2)	12.1 (1.2)
*Eliurus**	1	23.0 --	31.6 --	55.0 --	120.0 --	25.0 --	20.6 --
Macrotarsomys	3	19.7 (2.9)	33.8 (1.8)	74.0 (1.7)	143.0 (34.0)	27.5 (1.3)	17.7 (1.0)
Echinops	35	83.7 (5.6)	42.2 (1.3)	119.2 (17.4)	0	16.6 (0.6)	19.6 (1.5)
Microcebus	154	50.7 (9.9)	33.6 (1.7)	91.9 (9.5)	144.6 (11.0)	29.5 (3.2)	22.1 (1.3)

*This individual is a juvenile.

DISCUSSION

Macrotarsomys bastardi has a wide geographic distribution and is not considered endangered. However, it may be rare in certain parts of its range. Several other species of *Macrotarsomys* (*M. ingens* 64.5 g, *M. petteri* 105 g.) have a very restricted geographical range; indeed, the largest of the big-footed mice, *M. petteri*, was only recently described on the basis of the capture of a single individual in the forest of Mikea near the west coast of Madagascar (north of Toliara) (Goodman and Soarimalala 2005). From subfossil material, we can now consider that this species also occurred in southeastern Madagascar not long ago as its bones were found in the subfossil Holocene fauna of Andrahomana, a cave in southeastern Madagascar approximately 460 km away from the capture site in the Mikea forest (Goodman et al. 2006, Burney et al. 2008).

Despite years of fieldwork by numerous field researchers at Beza Mahafaly Special Reserve, *Macrotarsomys bastardi* has never previously been reported here. Nocturnal surveys and trapping were first conducted at Beza in 2002 during the rainy season, and subsequently in 2003 and 2004 during the dry season. Rats were observed in trees as well as on the ground; in July, 2003, ER found two rats in traps set (for *Microcebus*) at heights of about two meters above ground within the gallery forest. Intensive trapping was later initiated in October 2006; it was continued thereafter through the end of September 2007. During that year, many rats and mouse lemurs were captured and marked, but it was only then and indeed only during a two-month interval within that period (May and June 2007 – the early dry season) that endemic rodents were also successfully trapped. At Morondava, reproductive activity of *Macrotarsomys bastardi* peaks in April and May (Ganzhorn 2003). It is possible that it peaks a bit later at Beza, which is located considerably further to the south (393 km); thus the captures in May and June may correspond to the breeding season.

The fact that *Macrotarsomys bastardi* and *Eliurus myoxinus* were trapped in such low numbers signals their possible endangerment at Beza Mahafaly. Nevertheless, it is interesting to note that endemic small mammals do persist in small forest patches in Madagascar. It is noteworthy that Goodman et al. (1993) reported no endemic rodent presence in pellet samples of the Long-eared owl (*Asio madagascariensis*) collected just outside the reserve at Beza Mahafaly on the bank of the Ihazoara River during the year 1990. Pellet samples were collected during both wet and dry seasons (March, April, June and November). In contrast, at Bezavona (near Nahampoana, in southeast Madagascar, near Taolognaro), bones of two species of *Eliurus* (along with introduced rodents and other small mammals) were found in the pellets of the same owl, so it is unlikely that these rodents are unattractive to this formidable predator.

One of the factors that may influence capture frequencies is variation in diet. However, many rodents are attracted to banana, and should be lured by traps baited with banana. Rats and mice consume fruit as well as seeds, insects, and leaves, and both readily enter traps, particularly when set at low levels or on the ground. *Macrotarsomys bastardi* is strictly nocturnal and terrestrial, and similarly feeds on seeds and fruit (Carleton and Goodman 2003, Ganzhorn 2003).

Incidentally, *Cheirogaleus medius* has been listed as present at Beza Mahafaly (e.g. Mittermeier et al. 2006), but this is likely an error. This species has never been observed by researchers working on nocturnal mammals at Beza; bones of this species have not been recorded in owl pellets (largely *Microcebus*; see Goodman et al. 1993), and no *Cheirogaleus* entered traps set at any height during this study. It is unlikely

that diet explains this absence, as *Cheirogaleus* covets banana and is easily trapped in arboreal settings at other sites (e.g. Müller 1999, Blanco et al. in press).

Interactions among introduced and endemic small mammals will require further analysis. Ganzhorn (2003) studied the interactions of these species in the region of Morondava, and found that *Macrotarsomys* likes primary forests with a high density of trees of all diameters; it was never found in fragments smaller than 600 ha while rats tend not to like forests of large size, particularly those with trees of large diameter; instead, they prefer small forests with trees of moderate (5-9.9 cm) diameter (Ganzhorn 2003). At Beza Mahafaly, however, there are no large forests, and *M. bastardi* persists in small gallery forests. Over a century ago, Guillaume Grandidier (1902) described *Macrotarsomys bastardi* as found regularly in gallery forests bordering streams or rivers in southern Madagascar, alongside the very common *Lemur catta*.

The gallery forest at Beza is fairly disturbed; despite its being fenced, cattle are able to enter, and indeed, night and day, they are sometimes deliberately hidden in the gallery forest by local villagers to protect them from thieves. It is quite a bit smaller than 600 ha (Parcel 1 is only about 90 ha; Anne Axel, pers. comm.). The western portion of Parcel 1 is distant from the river and is correctly classified not as gallery forest but as transitional dry forest (Anne Axel, pers. comm.). Gallery forest extends beyond the confines of Parcel 1 to the north and south along the bank of the Sakamena River, but even so, the total area of gallery forest is not more than 115 ha (Anne Axel, pers. comm.).

Rats may be attracted to Parcel 1 at Beza simply because it is disturbed; these rodents may prefer habitats near human occupation, despite their existence in undisturbed forests in Madagascar. At Beza, both introduced rodents and big-footed mice are found on the ground, where they consume similar foods. In our study, rodents (whether endemic or introduced) were very rarely captured in the spiny forest, but *Echinops* was well represented there, as was *Microcebus griseorufus*. In the gallery forest where endemic and introduced rodents were found, the possibility that introduced rodents are having a negative impact on endemic species such as *Macrotarsomys bastardi* cannot be dismissed. We need to collect ecological data to record more directly possible negative interactions.

To further test the degree to which small endemic mammals are endangered at Beza Mahafaly, a broader trapping effort covering other parts of the three forests is certainly warranted; whereas our sampling effort was intensive, our sampling areas were rather small. Several species of small mammals that are known to exist at Beza Mahafaly (including *Geogale aurita*, *Setifer setosus*, and *Suncus etruscus madagascariensis*; Ratsirarson et al. 2001) never entered our traps. However, in the vicinity of the reserve, in 2003, Justine Salton and Rochelle Buffenstein had considerable success capturing *Echinops telfairi* in pitfall traps, which they used in addition to Sherman traps (Salton and Buffenstein 2004); they also captured *Geogale auritus* and *Setifer setosus* in a variety of traps. Thus we propose that, to maximize capture success, a wider variety of trap types, trap locations, and trap baits should be systematically tested. Certain species may prefer peanut butter, dried fish, or fresh meat to bananas. For ground traps, the type of ground habitat (e.g. distance to fallen logs, density of leaf litter) may be important (Stephenson 1994). For traps set in trees, the tree species and dimensions of the tree may be important.

Finally, traditional techniques for collecting behavioral data (including radio-tracking) should be employed to study interspecific interactions. If it can be shown that introduced rodents are indeed negatively impacting native species, a program of systematic eradication of *Rattus* and *Mus* should be considered.

CONCLUSIONS

A study of the small nocturnal mammals at Beza Mahafaly, involving a year-long effort of ground and tree capture, revealed the presence here of a species never before at this site, and the relative abundance of introduced rats and mice at this site. For the first time, *Macrotarsomys bastardi* was found in the gallery forest of Beza Mahafaly. We found no *Cheirogaleus* at Beza Mahafaly.

While rats and mice were infrequently (or never, in the case of mice) found in the spiny forest, and were most abundant in villages, rats and mice were both present in dry and gallery forests near villages or campsites.

Echinops telfairi and *Microcebus griseorufus* occur at Beza Mahafaly in both spiny and gallery forest; *Microcebus griseorufus* was more often trapped in the trees whereas *Echinops* was trapped exclusively on the ground (although it does climb trees, and has been trapped there in previous years). Although rats climb trees, they are frequently found on the ground. In contrast, endemic rodents were always trapped on the ground (*Macrotarsomys bastardi* is strictly terrestrial). *Mus* were also trapped on the ground far more frequently than in the trees.

Endemic rodents may occur at Beza in low density. We captured many more individuals belonging to introduced than endemic rodent species over a period of one year of intensive and random trapping. Introduced rodents may have negatively impacted endemic species at this site.

ACKNOWLEDGEMENTS

Many people helped with this research. For facilitating our study, we thank ANGAP, ESSA, and the Chief of BMSR. We are grateful to the following people who helped us collect the data: Viviane, Tsibara, Edward, Elahavelo, Efitiria, Enafa, Edabo, Dada, Etinahy, Filaoke, Fanomezana, Etala, Ebolo. We also thank the many local villagers who set the traps for rats and mice in and near their homes and who brought specimens to our campsite. Anne Axel generously provided unpublished data, and Darren Godfrey drew the map of Beza Mahafaly (Figure 1). Laurie Godfrey helped with the English and with statistical analysis of the data, and Natalie Vasey along with anonymous reviewers offered helpful comments on an earlier version of this manuscript. This research was funded by the International Foundation for Science, Wildlife Conservation Society, National Geographic Society, Primate Conservation, Inc. and the American Primatological Society (to Emilienne Rasoazanabary), as well as funds from the Universities of North Dakota and Massachusetts supporting Jacky Youssouf's travel to the USA.

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Behavior and diet of the Critically Endangered *Eulemur cinereiceps* in Manombo forest, southeast Madagascar

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ABSTRACT

Manombo Special Reserve is a parcel of rainforest along the southeastern coast of Madagascar, containing eight lemur species, including the White-collared brown lemur (*Eulemur cinereiceps* [*Eulemur albocollaris]*). Following a drastic cyclone in the region in January of 1997, the population of *E. cinereiceps* at Manombo was reduced by half. Results indicate that individuals of this critically endangered species at Manombo consume a total of 54 plant species belonging to 24 families, with over two-thirds of the diet comprised of ripe and unripe fruits. White-collared brown lemurs also opportunistically feed on novel food items and invasive plants in their recovering habitat. We report the first record of *E. cinereiceps* consuming a shelf fungus species growing on invasive trees. During feeding, lemurs tore pieces of the fungus from the trees with their hands and mouth (chewing cycle duration mean 0.28 s; SD 0.01). White-collared brown lemurs also consumed spicy fruits of a non-native plant species (*Aframomum angustifolium*) growing in highly disturbed open areas. Feeding bouts typically began by stripping away the outer covering with the anterior dentition, with pulp and seeds then consumed (chewing cycle duration mean 0.22 s; SD 0.005). This is the first record of consumption of either of these resources for any lemur species at Manombo. Ability to feed on items like *A. angustifolium* may permit *E. cinereiceps* to avoid competition with other species in this highly degraded forest environment.

RÉSUMÉ

La Réserve Spéciale de Manombo est un fragment de forêt dense humide de basse altitude et située le long de la côte Sud-est de Madagascar. Cette partie de forêt abrite au total huit espèces de lémuriens, y compris le Lémur à collier blanc (*Eulemur cinereiceps* [*Eulemur albocollaris*]). Le passage dramatique du cyclone Gretelle dans la région en janvier 1997 a réduit de moitié la taille de la population d'*E. cinereiceps* dans sa zone de distribution. Les résultats des études effectuées sur les individus restants de cette espèce, qui est classée comme Gravement Menacée, permettent d'énumérer un total de 54 espèces de plantes appartenant à 24 familles qui sont consommées par l'espèce. D'autre part, deux tiers du régime alimentaire d'*E. cinereiceps* sont représentés par des fruits mûrs ou non. Le Lémur à collier blanc consomme occasionnellement une quantité assez importante de plantes envahissantes pour assurer ses besoins nutritifs, ce qui n'est pas habituel dans l'histoire naturelle de la vie des lémuriens. La présente étude constitue également la première observation de consommation d'une espèce inconnue de champignon par les représentants d'*E. cinereiceps.* Dans le présent cas, ledit champignon venait juste de pousser sur un pied mort de *Cecropia peltata*, une espèce allogène et envahissante de la région. Durant la prise de nourriture, l'animal a arraché des morceaux du champignon sur l'arbre mort avec la main et puis la bouche. La partie consommée a été mâchée par l'animal pendant une période de 0,28 s. Le Lémur à collier blanc consomme aussi des fruits épicés d'une espèce de plante allogène (*Aframomum angustifolium*) qui ne pousse que dans des zones ouvertes et extrêmement dégradées. La prise de nourriture sur cette espèce de plante commence par l'enlèvement de la partie dure du fruit, pour cela l'animal utilise ses dents antérieures très puissantes, puis il tire soigneusement en même temps avec ses dents et sa langue la partie charnue et les graines. Cette prise de nourriture s'effectue pendant une période d'environ 0,22 s. C'était la première fois dans l'histoire des lémuriens de Manombo que des observations ont été effectuées sur un animal en train de manger des espèces de plantes inhabituelles. L'aptitude de manger des espèces de plantes telle que *A. angustifolium* pourrait permettre à *E. cinereiceps* d'éviter la compétition avec les autres espèces de lémuriens vivant dans cet environnement dégradé.

KEYWORDS: White-collared brown lemur, feeding behavior, habitat disturbance, invasive species, chewing cycle

INTRODUCTION

Manombo Special Reserve is a parcel of rainforest along the southeastern coast of Madagascar, containing eight lemur species, including the Critically Endangered *Eulemur cinereiceps*. Notably, this taxon has been featured on the World's 25 Most Endangered Primates list since 2004, and was until recently commonly referred to as *Eulemur albocollaris* (e.g. Mittermeier et al. 2006). Recent studies suggest that the species name *cinereiceps*

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has taxonomic priority and justify adopting such nomenclature at this time (Johnson et al. 2008 and references therein). For the sake of continuity with most of the published literature on the taxon we continue to use the common name White-collared brown lemur herein. Due to the extreme vulnerability of the White-collared brown lemur, it is imperative to document and understand the ecological conditions necessary for its survival.

Eulemur cinereiceps is a medium-sized lemur, with a body mass of about 2-2.5 kg. The species is sexually dichromatic; the male is generally dark with a white beard, whereas the female is rufous in color (Figure 1). White-collared brown lemurs live in social groups ranging in size between three and nine individuals (Mittermeier et al. 2004). *Eulemur cinereiceps* tends to be a frugivorous species, with a diet consisting mainly of fruit, and with a smaller proportion of the diet including leaves (mature and young), nectars and fungi (Johnson 2000). Like other *Eulemur* species, White-collared brown lemurs are cathemeral, or active during both day and night time, with the duration of nocturnal activity depending upon both season and food availability (Mittermeier et al. 2006). *Eulemur cinereiceps* exhibits fission-fusion social patterns and tends to be organized into multi-male / multi-female groups (Mittermeier et al. 2006). As in other primates, troop fusion occurs primarily during the period of abundance of natural resources in the forest, whereas troops undergo fission at times of food scarcity, such that smaller groups have sufficient access to resources to avoid spending energy in social conflicts (Ratsimbazafy 2002). Following cyclone Gretelle in the region in January of 1997, the population of *E. cinereiceps* at Manombo was reduced by half (Ratsimbazafy 2002). The habitat was drastically altered, with more than 90% of the autochthonous trees destroyed, decreasing availability of many of the plant species preferred by *E. cinereiceps* (Ratsimbazafy 2002). This study demonstrates that perhaps in addition to altering group size in disturbed forest parcels, individuals of this critically-endangered species have other strategies for overcoming food scarcity, such as opportunistic feeding on novel food items and invasive plants in their recovering habitat.

MANOMBO FOREST Located along the southeastern coast of Madagascar, the forest of Manombo is a good site to study the behaviour of wild *E. cinereiceps*. Manombo is accessible throughout the year, and in addition to providing insights into the effects of habitat disturbance upon lemur biology, it offers a convenient comparison between forest areas both with and without a strict conservation statute in place. The total area of Manombo forest is about 15,000 ha. The forest contains two main vegetation types: humid evergreen forest in altitudes between 40 and 120 m, and littoral forest lying at lower altitudes along the white coastal sands (Moat and Smith 2007). The present study focused on low altitude humid forest parcels encompassing a total of 13,000 ha (Figure 2). One parcel of humid dense forest (2,800 ha) is termed Manombo Special Reserve (SR), and is administrated by the ANGAP (National Association for the Management of the Protected Areas). The other parcel (10,000 ha) is called Manombo Classified Forest (CF), and is managed by the MEFT (*Ministère de l'Environnement, des Forêts et du Tourisme* – Ministry of Environment, Forests and Tourism) administered locally by the DREFT (*Direction Régionale de l'Environnement, des Forêts et du Tourisme* – Interregional Direction of Environment, Forests and Tourism). Although each portion of forest is considered protected by the government, the specific regulations governing forest use differs. For example, access to the SR is restricted, and activities like hunting and tree cutting are considered strictly illegal. In contrast, within the CF, use of timber and non-timber forest products is permitted under a policy of sustainable use. Despite the differing laws established for the good management of both portions of forests, each remains under pressure. Among the threats to long-term forest survival include slash and burn agriculture, logging, hunting and unsustainable use of secondary products. Without viable alternatives, such resources are needed by local villagers in order to survive. Because of the legislation and enforcement practices in place, unsustainable activities are more pronounced in the Classified Forest.

FIGURE 1. *Eulemur cinereiceps,* two males and one female (photo by F. Ralainasolo).

MANOMBO FOREST STRUCTURE Since the two portions of forests (SR and CF) are geographically so close to one another, few differences would be expected in their forest structure. Results of preliminary studies demonstrate that aspects of the overall structure and species composition of the two parcels of forest are indeed similar. A comparison of vegetation structure and composition was conducted in a one hectare botanical plot in each portion of forest. Variables recorded included plant species, tree height and DBH (Diameter at Breast Height). Results indicate that the two parcels (SR and CF) have a 9.8 m and 9.7 m medium tree height, respectively. Average DBH of the trees is about 8.2 cm for the SR and 7.7 cm for the CF. There were 2,567 plants recorded at the SR, as compared with 2,978 at the CF. Plant species belong to 47 families, the most common of which include Euphorbiaceae, Arecaceae, Cecropiaceae, Convallariaceae, Sapindaceae, Rubiaceae, Malvaceae, Lauraceae, Erythroxylaceae, Ebenaceae, Myrtaceae, Myristicaceae, and Salicaceae.

BEHAVIORAL SAMPLING METHODS Behavioral data collection took place between October 2006 and January 2007, and again from August to December 2007 to sample both the wet and dry seasons at Manombo. Behavioral observations were conducted between 0600-1700h each day, for a total of 517 hours, over 62 days. Although *Eulemur* may also feed at night (Donati et al. 2007), study observations were limited to daylight hours as visibility of food items was not possible in the dark. Two main data collection methods were employed: FR conducted instantaneous sampling at an interval of once per 5 minutes (Altman 1974), and a field assistant also collected data continuously. During the survey, FR conducted focal animal sampling, changing the focal individual every two hours. Data were recorded

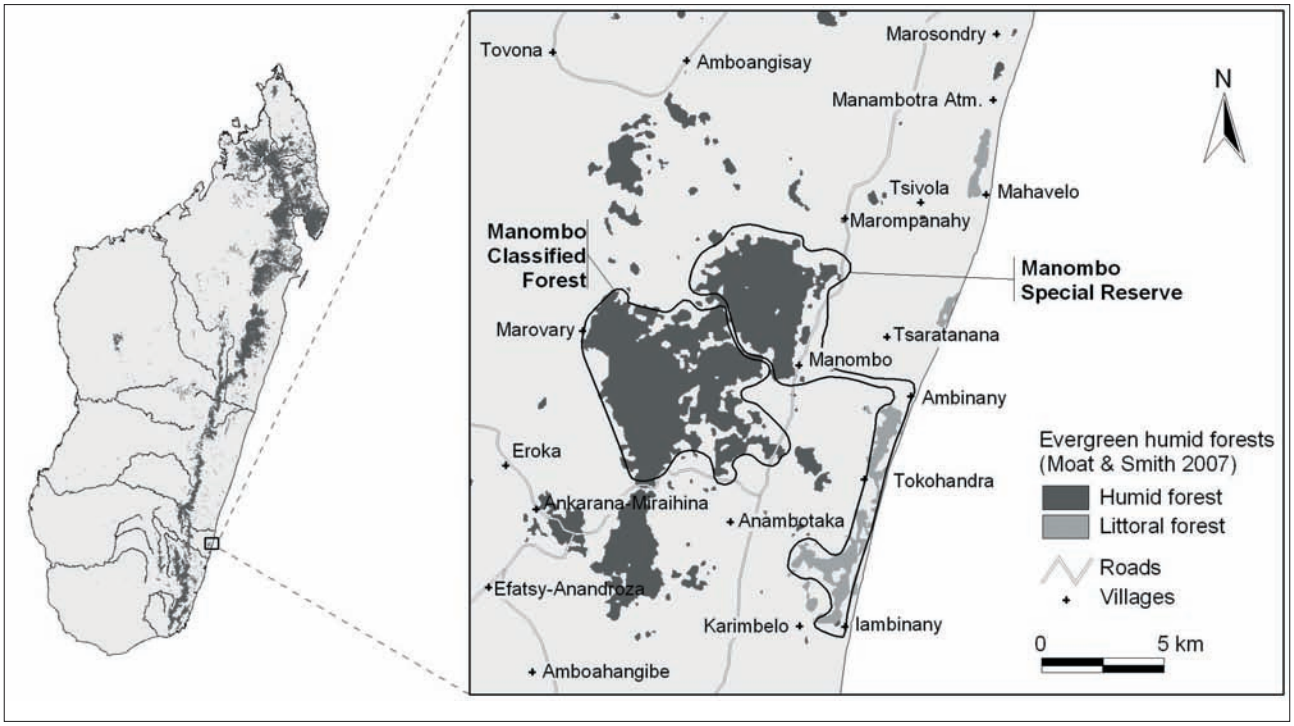


FIGURE 2. Location of the study area.

on all behaviours exhibited by the focal animal, in this case the behaviours are categorised into four main types: Resting (remaining in one place), Feeding (with the type of food item recorded), Moving (travelling or otherwise changing position), and lastly Social (contact between two or more individuals).

We studied two groups of animals in the Classified Forest and two groups of animals in the Special Reserve, and recorded the frequency and duration of time spent feeding on each plant species, and estimated the distance in meters between the ground and the position of the animal in the feeding tree. Dietary data included both the plant species that the animal fed upon, in addition to the plant part consumed. Plant parts were identified using a binocular (8x10), whereas the duration of time spent feeding on a given food item was estimated using a chronometer. Plant samples were collected for each species of plants that could not be readily identified by our team. Those samples are undergoing identification by specialists at PBZT (*Parc Botanique et Zoologique de Tsimbazaza*).

In addition, animals were opportunistically filmed during feeding on novel food items in order to compare chewing cycle durations. Chewing cycle duration relates to a number of properties of food items, for example, cycle durations can differ with bolus size or during times that food is grasped / manipulated (e.g. Dötsch 1986). Subjects were videotaped following methods described in Stevens (2003) and Stevens et al. (2006a and 2006b), using Sony DSC-H handheld digital video cameras positioned at a distance of 5 m from the study subjects to reduce parallax. Frame rates were optimized to catch rapid movements by splitting 30 Hz fields to achieve 60 Hz, and shutter speeds were set to reduce motion blur. Video sequences were imported into Peak Motus (version 9.0) and chewing cycle durations were calculated. The chewing cycle rate was defined as the duration of time (in seconds) between successive complete jaw closures.

RESULTS

ACTIVITY PATTERNS Activity patterns of *E. cinereiceps* are depicted in Figure 3. In the majority of the activity budget observations, the study animals were resting (over 40 % of the time) or engaging in social behaviors (over 30 % of the time). Feeding and traveling each constituted about 12 % of the activities recorded (Figure 3). Note that animal visibility did not present a significant challenge during the study.

DIETARY COMPOSITION As expected, more than 67 % of the foods eaten by *E. cinereiceps* were ripe or unripe fruits. White-collared brown lemurs also consumed a considerable quantity of leaves. During the survey, a total of 54 plant species belonging to 24 families were consumed by *E. cinereiceps*. Table 1 lists the items consumed by *E. cinereiceps* during the wet and dry seasons. Notably, only 14 food species were consumed during the dry season, compared with 51 food species consumed during the wet season. A total of 11 food species were consumed during both wet and dry seasons. Figure 4 depicts just a few of the species consumed by *E. cinereiceps*. Although

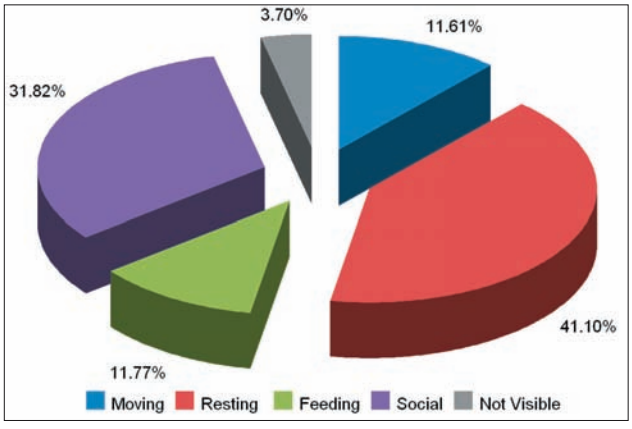


FIGURE 3. Activity budget of *Eulemur cinereiceps*.

TABLE 1. List of plant species consumed by *Eulemur cinereiceps*. Abbreviations as follow: RF (ripe fruit), UF (unripe fruit), YL (young leaves), ML (mature leaves), FL (flowers), NEC (nectar), F (fungus), D (dry season), W (wet season).

Family	Scientific name	Vernacular name	Part consumed	Season consumed
Acanthaceae	*Mendocia flagellaris*	*Vahy*	RF,YL,ML	D, W
Anisophylleaceae	*Anisophyllea* sp	*Hazomamy*	UF	W
Annonaceae	*Ambavia* sp	*Robavy*	YL,RF	W
Apocinaceae	*Landolphia platyclada*	*Vahateso*	RF	W
Araliaceae	*Schefflera*	*Vatsilambato*	UF	W
Arecaceae	*Dypsis* sp	*Vonitra*	RF	D, W
Asteropeiaceae	*Asteropeia* sp	*Hazoseha*		W
Celastraceae	*Astrocassine* sp	*Maronono*	FL	W
Cecropiaceae	*Cecropia peltata*	*Tanatana*	UF,RF	D, W
Clusiaceae	*Symphonia* sp	*Ditsaka*	RF	W
Erythroxylaceae	*Erythroxylum sphaeranthum*	*Menahihy*	YL	W
Euphorbiaceae	?	*Baby*	RF	D
Euphorbiaceae	*Vepris* sp	*Kalavelo*	ML	W
Euphorbiaceae	*Cleistanthus bovinianus*	*Maroampotony*	YL	W
Euphorbiaceae	*Macaranga obovata*	*Mokarana*	UF,RF	W
Fabaceae	*Albizia* sp	*Ambilazo*	YL	W
Fabaceae	*Cynometra* sp	*Variotra*	YL	D
Linaceae	*Hugonia* sp	*Vahemavo*	RF	W
Malvaceae	*Dombeya* sp	*Hafotra*	UF,RF	D, W
Menispermaceae	*Burasaia madagascariensis*	*Masomposaina*	RF	W
Moraceae	*Ficus* sp	*Amota*	RF	D, W
Moraceae	*Antiaris* sp	*Ampa*	RF	D, W
Moraceae	*Ficus* sp	*Apalimaraha*	RF	W
Moraceae	*Ficus* sp	*Haragny*	RF	D, W
Moraceae	*Trilepisium boivinianum*	*Kivozo*	RF	W
Moraceae	*Ficus reflexa*	*Laza*	RF	D, W
Moraceae	*Micronychia* sp	*Haraseha*	RF,ML	W
Myrtaceae	*Syzygium emirnensis*	*Rotra*	YL	W
Oleaceae	*Noronhia myrtoides*	*Tsilaitra*	UF	W
Pandanaceae	*Pandanus* sp	*Tsirika*	RF	W
Rubiaceae	*Mussaenda arcuata*	*Anandaingo*	UF	W
Malvaceae	*Dombeya* sp	*Valotra*	YL	W
Salicaceae	?	*Fotsakara*	RF	W
Salicaceae	*Homalium* sp	*Hazofotsy*	UF	W
Sapindaceae	*Macphersonia gracilis*	*Marombody*	YL	W
Sapindaceae	*Macphersonia madagascariensis*	*Sanira*	RF	W
Sapotaceae	*Sideroxylon* sp	*Aboladitra*	RF	D
Sapotaceae	*Labramia louvelii*	*Nato*	RF,UF	D, W
Sapotaceae	*Faucherea* sp	*Natoboaka*	RF	W
Sapotaceae	*Chrysophyllum boivinianum*	*Rehiaka*	YL	W
Sphaerosepalaceae	*Rhopalocarpus* sp	*Tandria*	YL	W
Strelitziaceae	*Ravenala madagascariensis*	*Ravinala*	NEC	W
Verbenaceae	*Lantana camara*	*Redriaka*	UF,RF	D, W
Zingiberaceae	*Aframomum* sp	*Longoza*	RF	W
?	?	*Angoto*	RF	W
?	?	*Fotsignana*	RF	W
?	?	*Lalotsivoatoa*	UF	W
?	?	*Fungus indet.*		D, W
?	?	*Tendrokazo*	UF,RF	W
?	?	*Vahapiso*	RF	W
?	?	*Vahimatavy*	ML	W
?	?	*Vandremba*	ML,YL	W
?	?	*Voalatakakoho*	RF	W
?	?	*Voasingiry*	UF,RF	W

FIGURE 4. Common dietary items of *Eulemur cinereiceps*, A) *Ficus* sp., B) *Aframomum angustifolium*, C) *Pandanus* sp., D) *Clidemia hirta*, E) *Cynometra* sp., F) unidentified fungus.

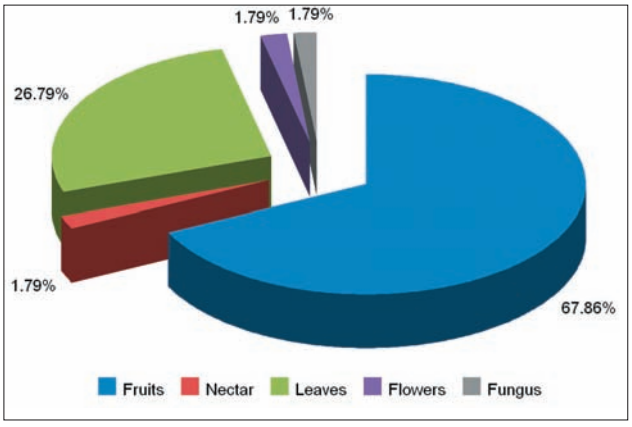
E. cinereiceps is considered a frugivorous species (Mittermeier et al. 2006), individuals also included leaves, nectars and fungi in their diets. Notably, White-collared brown lemurs did not eat the same parts of each plant species (Figure 5).

CONSUMPTION OF NON-NATIVE FOOD ITEMS Of the 54 plant species eaten by White-collared brown lemurs, four are classified as introduced species, and non-native plants constituted over 23 % of the feeding records of these endangered lemurs. Notably, this is the first record of *E. cinereiceps* consuming an undetermined fungus species growing on the trunks of dead *Cecropia peltata* (Cecropiaceae) trees. Interestingly, *Cecropia* is an invasive plant that is common in disturbed forest areas (Weber 2003). During feeding, lemurs tore pieces of the whitish-yellow fungus from the trees with their hands and mouth. The fungus appeared to be fairly resistant to manual tearing, and pieces were consumed using chewing cycles of over one quarter of a second in duration (mean 0.28 s; SD 0.01). White-collared brown lemurs were also observed consuming spicy fruits of a non-native plant species (*Aframomum angustifolium* Zingiberaceae). Feeding bouts typically began by holding the fruit with both hands and stripping away the outer covering with the anterior dentition. The pulp and seeds were then rapidly consumed, with shorter chewing cycle duration (mean 0.22 s; SD 0.005). After consuming the contents, they discarded the remaining outer covering, and quickly licked their fingers and palms. This is the first record of consumption of either of these resources for any of the lemur species at Manombo, and differences in chewing cycle duration may result from differences in the sizes of bites taken, as well as differences in manipulation / handling of the two types of food items during consumption.

DISCUSSION

The passage of cyclone Gretelle in 1997 destroyed 75 % of the trees in the Special Reserve and 50 % of the trees in the Classified Forest (Ratsimbazafy 2002). Overall, the forest of Manombo was severely damaged, with more than 90 % of the autochthonous trees destroyed (Ratsimbazafy 2002). Population sizes of lemur species inhabiting the forest were reduced by half (Ratsimbazafy 2002). It is likely that for a time, resource availability at Manombo was insufficient to support the previous population size, although evidence is mounting that population is now recovering (S. Johnson, pers. comm.). The location of Manombo in southeastern Madagascar renders it subject to frequent cyclone activity, so it is likely that the lemur fauna residing in this forest have been obliged to adapt to cyclical challenges in habitat quality. Our observations reveal that the Critically Endangered *Eulemur cinereiceps* currently

FIGURE 5. Proportions of different plant parts consumed by *Eulemur cinereiceps*.



adopts important strategies to overcome food scarcity by taking advantage of invasive species.

Eulemur cinereiceps at Manombo were observed spending up to 25 % of their feeding time opportunistically consuming non-native plant and fungus species in their recovering habitat. This report constitutes the first record of *E. cinereiceps* consuming an undetermined fungus species that grows on the trunks of dead *Cecropia peltata* trees. Notably, *Cecropia* is one of the non-native species at Manombo, indicating that introduced vegetation may provide a high proportion of fallback food opportunities in altered habitats. White-collared brown lemurs were also observed consuming spicy fruits of another non-native plant species (*Aframomum angustifolium*) that grows in a highly disturbed, open area in the forest. Feeding on items such as *A. angustifolium* is likely to enable *E. cinereiceps* to cope with habitat destruction, and perhaps in part to avoid competition with other lemurs such as *Varecia* for native plants in this highly disturbed humid forest habitat. The plant species consumed by Varecia and E. cinereiceps at Manombo overlaps by as much as 75% (Ratsimbasafy, pers. obs.). To date, *Varecia* has not been observed to feed on *A. angustifolium*.

CONCLUSIONS

Habitat loss due to natural and anthropogenic causes presents a major challenge for the conservation of endangered Malagasy faunas. Cyclical storms can drastically alter habitats of animals with low population sizes that are already on the brink of extinction, rendering their chances of long-term survival vanishingly slim. The situation is complicated by the fact that local communities also rely on forest resources for survival. Animals that are capable of taking advantage of a broad range of dietary resources, including plant species introduced by humans, may obtain an edge in surviving during times of food scarcity. White-collared brown lemurs at Manombo spend over a fifth of their feeding time eating plant parts of three introduced species – *Lantana camara* Verbenaceae, *Aframomum* sp. and *Cecropia peltata*. Moreover, consumption of a fungus that grows on the trunk of dead *Cecropia peltata* constitutes an additional component of the diet. The ability to feed on items such as fungi and spicy fruits of *Aframomum angustifolium* may permit *Eulemur cinereiceps* to avoid competition with other species in this highly degraded forest environment. Such dietary flexibility and opportunistic behaviour may prove to be the key to survival for this critically endangered lemur on an ever-changing and often challenging landscape.

ACKNOWLEDGMENTS

We thank the following people and organizations for assistance in this study: our field guides Kosinisy, Faly Razafy, Tranga François Ramarolahy, and Tsilefa; The Ministère de l'Environnement, des Forêts et du Tourisme, and ANGAP (Association Nationale pour la Gestion des Aires Protégées) for research permits and logistical assistance; ANGAP agent, Salvador; and the research teams of Dr. Ed Louis and Dr. Steig Johnson. Two anonymous reviewers provided input that improved the manuscript. We thank Steve Howard for his support through the African Studies Program, Center for International Studies, Ohio University. Partial funding for kinematics was provided by the Ohio University College of Osteopathic Medicine. We especially recognize the local community in Manombo for whom the forest makes all the difference.

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A conservation assessment of the amphibians and reptiles of the Forêt d'Ambre Special Reserve, north Madagascar

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ABSTRACT

We surveyed the lowland rainforest of the Forêt d'Ambre Special Reserve in north Madagascar for amphibians and reptiles. We recorded a total of 20 amphibian and 39 reptile species via opportunistic searching and pitfall trapping in the first published survey to focus on this area. Consequently most of the species found were new records for the area. Approximately half of the species (51%) were only found in relatively undisturbed areas of forest and 61% appear to be restricted to lowland rainforest below 900 m elevation. The most vulnerable elements of this herpetofauna are the three species that appear to be locally endemic to Forêt d'Ambre (according to the current knowledge): *Boophis baetkei*, *Brookesia* sp. nov., and *Rhombophryne* sp. nov. An additional 25 species are considered regional endemics, 14 species are threatened according to the 2007 Red List of Threatened Species and 15 species are listed on the CITES appendices. This paper contributes to the current understanding of Malagasy patterns of biodiversity by documenting the composition, geographical and ecological distribution of the herpetofauna found at this site. Despite its protected status, currently the Reserve is not being managed sufficiently as it is subject to numerous human-induced environmental problems resulting in habitat destruction and should therefore be considered a high conservation management priority. Herein, we provide conservation and development recommendations for this highly diverse site of herpetological importance. Furthermore, we provide an updated and revised species list of the amphibians and reptiles of Montagne d'Ambre National Park and a species list for the private Fontenay Nature Park.

RÉSUMÉ

Lors d'un inventaire des espèces d'amphibiens et de reptiles de la Réserve Spéciale de la Forêt d'Ambre au nord de Madagascar, nous avons recensés un total de 20 espèces d'amphibiens et de 39 espèces de reptiles par le biais d'échantillonnages directs et avec des trous-pièges « pitfall traps », constituant ainsi le premier résultat d'inventaire publié sur cette zone. De sorte que toutes les espèces répertoriées constituent de nouvelles données pour cette région. Environ une moitié des espèces (51%) n'a été trouvée que dans des zones forestières peu perturbées et 61% se limitent à la forêt pluviale de basse altitude (altitude inférieure à 900 m). Les éléments les plus vulnérables de cette herpétofaune sont les trois espèces qui semblent être localement endémiques, à savoir *Boophis baetkei*, *Brookesia* sp. nov. et *Rhombophryne* sp. nov. Par ailleurs, 25 autres espèces sont endémiques de la région, 14 espèces sont inscrites sur la liste rouge IUCN 2007 des espèces menacées et 15 sont inscrites dans les annexes de la CITES. Ce travail contribue à une meilleure compréhension des schémas de la biodiversité malgache en documentant la composition ainsi que la distribution géographique et écologique de l'herpétofaune recensée sur ce site. Malgré son statut de protection, la réserve est soumise à de nombreuses perturbations d'origine anthropique entrainant une destruction de l'habitat et devrait à ce titre être considérée comme une zone prioritaire en matière de conservation. Nous formulons des recommandations pour la conservation et le développement de ces sites qui présentent une diversité faunique importance. Nous fournissons également une liste mise à jour et révisée des amphibiens et des reptiles du Parc National de la Montagne d'Ambre, ainsi qu'une liste du parc privé 'Fontenay Nature Park'.

KEYWORDS: Amphibia; Conservation; Forêt d'Ambre; Madagascar; Montagne d'Ambre; Reptilia.

INTRODUCTION

The Forêt d'Ambre is an area of forest located at the foot of the Montagne d'Ambre mountain complex, which runs north-south at the extreme northern tip of Madagascar (Figure 1). Part of the subhumid bioclimatic zone originally defined by Cornet (1974) and further utilized by Schatz (2000), it is subject to marked seasonal variation, with a distinct and relatively long dry season followed by a wet season lasting from December to April. The annual precipitation of this location is higher than that received by the town Antsiranana, which has a mean of 980 mm (Nicoll and Langrand 1989), and is probably lower to that received at

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the adjacent Montagne d'Ambre National Park (e.g. Station des Roussettes, mean 2,378 mm). As a result the vegetation of the Forêt d'Ambre is distinctly mesic and has been described as transitional between lowland rainforest (at higher elevations) and dry deciduous western forest (at lower elevations) (White 1983, Raxworthy and Nussbaum 1994). Due to its close proximity to the town of Antsiranana and other large communes such as Sakaramy and Joffreville, the forest is also characterized by semi-disturbed and heavily degraded areas of anthropogenically altered habitat.

The partial isolation of the low altitude dry deciduous forest of this site from the five other major localized areas of dry deciduous forest (Analamera, Ankarana, Daraina, Montagne des Français and Orangea) located in the extreme north of Madagascar is believed to be as a result of human settlement [estimated at approximately 1,500-2,000 years ago (Hurles et al. 2005)] and subsequent anthropogenic deforestation (Vallan 2000, Vallan 2002, D'Cruze et al. 2006). However, it is important to note that the sub-arid habitats which separate the rainforest within the Montagne d'Ambre complex from the rest of the major eastern rainforest block do not appear to have been created by the same recent human activity (Raxworthy and Nussbaum 1994). As the Montagne d'Ambre mountain complex is volcanic in origin, composed of basaltic rock formed about 14 million years ago (Du Puy and Moat 1996), it probably received more continuous precipitation during dry periods to support a forest cover which may have been partially isolated for millions of years from other northern and eastern forest blocks (Raxworthy and Nussbaum 1994).

The Forêt d'Ambre Special Reserve with a surface area of 4,810 ha (S12°20'-S12°30', E49°09'-E49°14') was formally created in 1958. This IUCN Category II protected area includes forest between 150 and 1,143 m a.s.l. and is characterized by numerous high-standing hills, ridges and plateaus interspersed with valleys, channels and gullies. Several rivers and streams flow through the Reserve and a permanent body of water known locally as Lac Mahery can be found at 343 m a.s.l. Further protection is provided to forest in this mountain range by the adjacent Montagne d'Ambre National Park (18,200 ha) which was also created in 1958. Both the Forêt d'Ambre Special Reserve and the Montagne d'Ambre National Park are currently managed by ANGAP ('Association Nationale pour la Gestion des Aires Protégées'). In addition, a small privately owned and managed area of forest known as the 'Fontenay Nature Park' borders both of these protected areas.

Madagascar is blessed with a rich herpetofauna comprising over 600 species of reptiles and amphibians, more than 95 % of which are endemic to the Malagasy region (Glaw and Vences 2007). Based on specific combinations of climate, topography and vegetation, Madagascar has been traditionally divided into five or six biogeographic zones (Cornet 1974, Schatz 2000), More recently, Wilmé et al. (2006) divided the island into 10 areas of endemism according to the main watersheds and species distribution data. Among these, the areas characterized by humid rainforest (predominantly the east of the island) have attracted most of the attention from researchers because of their high biodiversity and advanced conservation needs. However, fieldwork conducted in recent years has begun to reveal the extraordinary importance of the extreme north as a biological center of herpetological diversity and endemism, which has included the discovery of a multitude of undescribed herpetological taxa (Raxworthy and Nussbaum 1994, Mori et al. 2006, D'Cruze et al. 2006, 2007, Rakotondravony 2006).

Despite the relatively old age of the Special Reserve and the interesting biogeographic history of the site, prior to this study virtually nothing was known about its herpetofauna. Specimens had been collected from the Montagne d'Ambre complex for more than 100 years, with the earliest herpetological collection (deposited in the Musée National d'Histoire Naturelle, Paris) made by Alluaud and Belly in 1893 (Mocquard 1895). Typically, however these specimens lack precise locality data, which is a significant problem because of the wide elevational range and diverse array of habitat types in the region. Species were often represented by a single specimen, which made it impossible to understand character variation within local populations and increased the risk of taxonomic errors. As a result no comprehensive species list for the amphibians and reptiles of the Forêt d'Ambre Special Reserve has ever been published. In contrast several vertebrate species lists have been produced for the adjacent Montagne d'Ambre National Park (IUCN / UNEP / WWF 1987, Nicoll and Langrand 1989, Andreone 1991, Raxworthy and Nussbaum 1994). However, even the most recent survey conducted by Raxworthy and Nussbaum (1994) was done over a decade ago and is in need of revision in order to keep up with new discoveries and taxonomic progress.

Given the lack of published information regarding this important site of conservation, we conducted a rapid survey of amphibians and reptiles in order to (1) update the existing knowledge regarding the composition, geographical and ecological distribution of the herpetofauna of the Forêt d'Ambre Special Reserve, (2) highlight the herpetological diversity of this area and identify the current threats to its conservation, (3) review the existing conservation initiatives and (4) provide recommendations that will facilitate the development of an effective and sustainable management plan for the reserve. We also take the opportunity to provide a preliminary species list for the Fontenay Nature Park and an updated species list for the Montagne d'Ambre National Park.

STUDY SITES Field work was centered at two camps situated along the road which runs along the eastern edge of the Reserve from Sakaramy to Joffreville, which facilitated exploration of the full altitudinal range found within the Forêt d'Ambre Special Reserve and adjacent unprotected areas (150-1,143 m). Camp 1, Hotely Tsara 'Lasopy' Antanambetsara, S12º27.98', E49º 13.82', 454 m altitude, adjacent to low altitude rainforest, was occupied from 18 to 25 February 2008. Camp 2, Le Domaine de Fontenay, S12º 29.70', E49º12.15', 720 m altitude, also adjacent to low altitude rainforest, was occupied from 25 to 29 February 2008. In addition, short excursions were carried out by a second team in the Fontenay Nature Park (S12º29.70', E49º12.15', between 19 and 28 February 2008) and to the Lac Mahery (27 February 2008). An initial excursion to Forêt d'Ambre was carried out on 12 March 2007. Fieldwork in Montagne d'Ambre National Park was carried out by many different research teams during several excursions between 1994 and 2008 and most of the results are summarized in Glaw and Vences (2007).

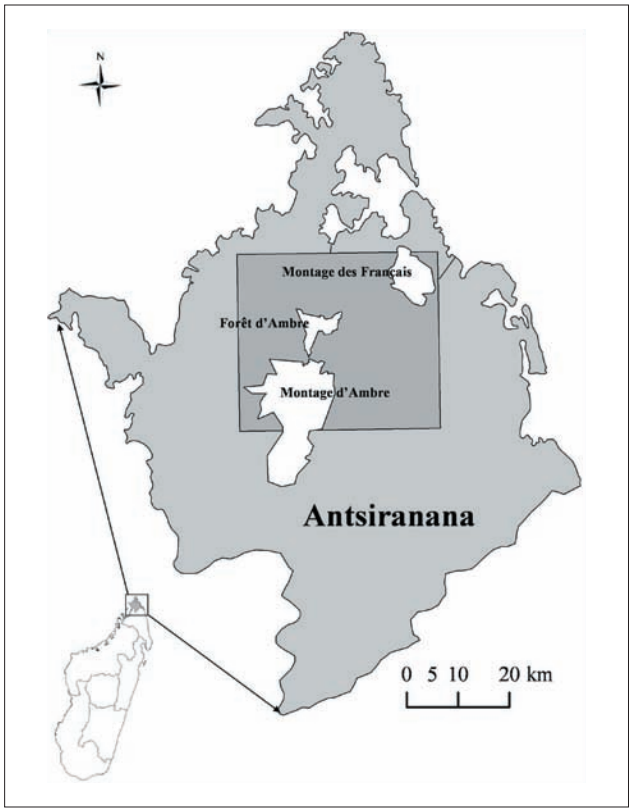

FIGURE 1. Map of northern Madagascar. The grey square depicts the location of the Forêt d'Ambre Special Reserve, the Montagne d'Ambre National Park and Montagne des Français within the Antsiranana Province.

MATERIALS AND METHODS

Due to the lack of field information regarding the herpetofauna of Fôret d'Ambre we used a wide range of sampling methods in order to collect data for as many species as possible. The main survey techniques we utilized were pitfall trapping with drift fences, opportunistic searching, refuge examination, and searching for calling frogs. We also made a concerted effort to identify anthropogenic activities that represent threats to the conservation of this area. We used three 100 m pitfall traplines with drift fences as described in Raxworthy and Nussbaum (1994), which were left in place for a total of eight days. We conducted opportunistic searches (D'Cruze et al. 2007) across the full range of altitudes and habitats – night and day searching – in order to reveal the presence of species not captured by the other methods. We also made direct counts along line transects to identify species and assess their distribution and abundance. We specifically targeted calling anurans after rainfall. We classified the species encountered during this survey using a system similar to that used by Wilson and McCranie (2004) and D'Cruze et al. (2006, 2007) that can be summarized as follows: Abundant (large numbers encountered on a regular basis), common (encountered on a regular basis), infrequent (unpredictable, few individuals seen), or rare (rarely seen). These classifications are based on data collected using all survey techniques and refer to the total number of individuals encountered for each species. Finally we also estimated the altitudinal range for all of the species currently recorded from the Montagne d'Ambre complex. We used the minimum and maximum elevations [combined data of our surveys and that of Raxworthy and Nussbaum (1994)] to calculate the elevational range of each species. This method makes the assumption that each species is distributed continuously through the minimum and maximum elevation recorded.

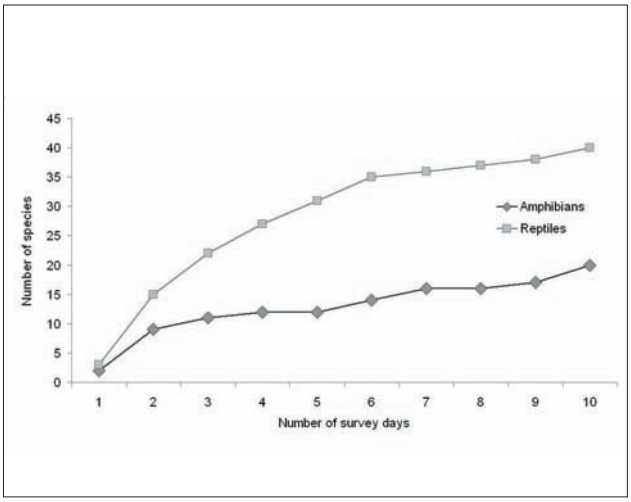

FIGURE 2. Species accumulation curve for amphibians and reptiles found in this study at the Forêt d'Ambre Special Reserve.

The following information was recorded for each collected specimen: date, latitude, longitude, habitat, microhabitat and altitude. We also made color notes and took photographs. We took voucher specimens (preserved in 70 % ethanol) and tissue samples for all voucher specimens. Reptile and amphibian specimens were deposited at the Zoologische Staatssammlung München (ZSM) and at the Université d'Antananarivo, Département de Biologie Animale (UADBA). A list of specimens can be found in Appendix I.

RESULTS

During this survey we recorded a total of 20 amphibian and 39 reptile species in the Forêt d'Ambre, giving a total herpetofaunal diversity of 59 species. A single species, *Madascincus* cf. *polleni*, was the only species captured in the pitfall traps. Explicit details of pitfall trap captures are not provided as they yielded very poor results. The species accumulation curves (Figure 2) indicate that we did not encounter all the reptile and amphibian species present in the area. However, it can now be assumed that the herpetofauna of Forêt d'Ambre consists of at least 24 species of lizard (41 %), 15 snakes (25 %) and 20 anurans (34 %). We classify a total of 3 species (5 %) as abundant, 14 (24 %) as common, 21 (36 %) as infrequent and 21 (36 %) as rare (Table 1). A complete species list is given in Table 1 along with the current CITES listing (CITES Species Database, Geneva, Switzerland) and IUCN status (IUCN Red List of Threatened Species 2007, Species Survival Commission, Gland, Switzerland) for each of the relevant species. Table 1 also includes ecological data for each species including habitat type (classified as either forest or anthropogenically disturbed habitat), ecological distribution and relative abundance. We also provide a preliminary species list of amphibians and reptiles for the Fontenay Nature Park containing 36 species as well as an updated species list for the Montagne d'Ambre National Park including 75 species (Table 2). Photographic evidence of some of the species encountered during this study are provided in Figure 3 Plate A - D.

TABLE 1. Conservation Status and distribution of the amphibian and reptile species found in Forêt d'Ambre Special Reserve during this study. Abbreviations: Relative Abundance: A = abundant, C = common, I = infrequent, R = rare; Ecological Distribution: AB = arboreal, T = terrestrial, S = semiaquatic; Habitat: F = forest, A = anthropogenically disturbed habitat; Endemicity: E = endemic to Madagascar, RE = endemic to the north of Madagascar (regional endemic), N = not endemic to Madagascar.

Species	IUCN	CITES	Relative Abundance	Ecological Distribution	Habitat	Endemic
Amphibia						
Microhylidae						
Cophyla sp. nov.			R	AB	A	RE
Platypelis grandis	LC		R	AB	F	E
Rhombophryne sp. nov.			C	T	F	RE
Stumpffia sp.			C	T	F	RE
Ptychadenidae						
Ptychadena mascareniensis	LC		C	T, S	A	E
Mantellidae						
Aglyptodactylus madagascariensis	LC		I	T	A, F	E
Aglyptodactylus securifer	LC		I	T	A, F	E
Blommersia wittei	LC		A	T	F	E
Boophis baetkei	EN		R	AB	F	RE
Boophis brachychir	DD		I	AB	F	RE
Boophis septentrionalis	DD		I	AB	F	RE
Boophis sp. nov. aff. *brachychir*			R	AB	F	RE
Boophis sp. nov. aff. *madagascariensis* "north"			I	AB	F	RE
Boophis tephraeomystax	LC		I	AB, T	A, F	E
Gephyromantis granulatus	LC		I	T, S	F	RE
Gephyromantis pseudoasper	LC		I	T, S	F	RE
Mantella viridis	EN	II	R	T	F	RE
Mantidactylus ambreensis	LC		I	T, S	F	RE
Mantidactylus bellyi			C	T, S	F	RE
Mantidactylus aff. *betsileanus*			R	T, S	F	RE
Reptilia						
Chamaeleonidae						
Brookesia ebenaui		II	C	AB	F	RE
Brookesia sp. nov.		(II)	C	AB	F	RE
Brookesia stumpffi		II	C	AB	F	E
Furcifer oustaleti		II	A	AB	A	E
Furcifer pardalis		II	A	AB	A, F	E
Furcifer petteri		II	C	AB	F	RE
Gekkonidae						
Blaesodactylus boivini			C	AB	A, F	RE
Geckolepis cf. *maculata*			R	AB	F	E
Hemidactylus frenatus			I	AB	A	N
Lygodactylus cf. *heterurus*			R	AB	A	RE
Paroedura cf. *oviceps*			I	T	F	E
Paroedura stumpffi			I	T	F	E
Phelsuma abbotti chekei	LC	II	I	AB	A	E
Phelsuma lineata dorsivittata		II	I	AB	A, F	E
Phelsuma grandis		II	C	AB	A, F	E
Uroplatus alluaudi		II	R	AB	A	RE
Uroplatus sp. nov. aff. *ebenaui*		II	R	AB	A, F	E
Uroplatus sp. nov. aff. *henkeli*		II	C	AB	A, F	E
Uroplatus sikorae		II	C	AB	A, F	E
Uroplatus giganteus		II	I	AB	A, F	RE
Gerrhosauridae						
Zonosaurus haraldmeieri			I	T	F	RE
Scincidae						
Madascincus cf. *polleni*			I	T	F	E

Trachylepis elegans			I	T	A	E
Trachylepis tavaratra			I	T	A	RE
Boidae						
Sanzinia madagascariensis volontany	VU		I	AB, T	A, F	E
Colubridae sensu lato						
Alluaudina bellyi			C	T	A, F	E
Dromicodryas quadrilineatus			R	T	A	E
Ithycyphus miniatus			R	AB	A	E
Leioheterodon madagascariensis			C	T	A, F	E
Leioheterodon modestus			R	T	A	E
Liophidium torquatum			I	T	F	E
Mimophis mahfalensis			R	T	A	E
Pseudoxyrhopus microps			R	T	A	E
Pseudoxyrhopus cf. *quinquelineatus*			R	T	?	E
Stenophis granuliceps			R	AB	F	RE
Stenophis inopinae			R	AB	F	RE
Stenophis cf. *variabilis*			R	AB	F	E
Thamnosophis lateralis			R	T	F	E
Thamnosophis martae			R	T	F	E

Plate A: *Uroplatus* sp. nov. aff. *ebenaui*

Plate B: *Uroplatus giganteus*

Plate C: *Boophis* sp. nov. aff. *madagascariensis* „north"

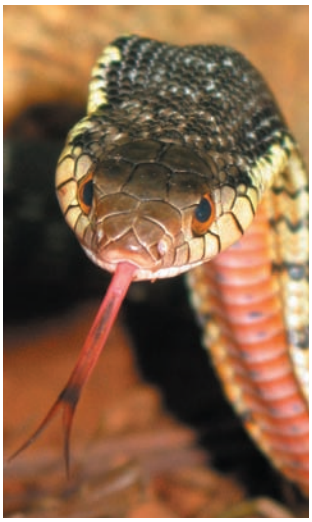

Plate D: *Leioheterodon madagascariensis*

FIGURE 3. Photographic documentation of some of the species encountered in Forêt d'Ambre.

BIOGEOGRAPHY AND CONSERVATION STATUS Almost all of these species are naturally endemic to Madagascar, with just one, *Hemidactylus frenatus*, known for its cosmopolitan distribution. The following species are currently known only from this Special Reserve: *Boophis baetkei*, *Brookesia* sp. nov., and *Rhombophryne* sp. nov. Furthermore, we recorded 25 species (42 %) that are regional endemics restricted to only a few places in north Madagascar (Table 1). Two species are listed as data deficient, two are listed as endangered (as of the original description, see Köhler et al. 2008), one is listed as vulnerable and 10 are listed as least concern on the 2007 IUCN Red List of Threatened Species. A total of 15 species are listed on the CITES appendices.

HABITAT AND DISTRIBUTION With regards to habitat quality, 30 species (51 %), were only observed in relatively undisturbed forest (Table 1). A total of 14 species (24 %) were observed in both forest and anthropogenically disturbed habitat. Only 14 species (24 %) were observed in anthropogenically disturbed habitat. In terms of vertical positioning within the undisturbed habitat, we found 22 species (37 %) only in terrestrial situations, 29 (49 %) only in typically arboreal situations, and 2 (3 %) in both (Table 1). We observed six species (10 %) in both semi-aquatic and terrestrial situations.

ALTITUDINAL DISTRIBUTION The altitudinal distribution of the amphibians and reptiles is restricted in most cases to just a portion of the full altitudinal range of the Montagne d'Ambre complex. A distinct transitional altitude is apparent for many species at 900 m. Of the 59 species encountered at Forêt d'Ambre Special Reserve during this survey, 36 (61 %) have been found exclusively at or below 900 m and 22 (37 %) have been found above and below 900 m (Table 2).

DISCUSSION

AN IMPORTANT SITE OF HERPETOLOGICAL DIVERSITY AND ENDEMISM The extremely high level of regional endemism seen in the herpetofauna, immediately emphasizes the value of the Forêt d'Ambre Special Reserve as a key site

TABLE 2. Inventory list and altitudinal distribution for the amphibian and reptile species of Montagne d'Ambre National Park, Fontenay Nature Park and the Forêt d'Ambre Special Reserve (see text for literature sources): Survey Data: + = present; Altitude: ? = unknown.

Species	Montagne d'Ambre	Fontenay	Forêt d'Ambre	Altitude
Amphibia				
Microhylidae				
Cophyla sp. nov.	+	+	+	500-1,250
Platypelis grandis	+		+	550-1,050
Rhombophryne laevipes	+			900-1,200
Rhombophryne sp. nov.			+	400-500
Stumpffia sp. 1	+			600-1,250
Stumpffia sp. 2	+	+	+	400-650
Hyperoliidae				
Heterixalus cf. *carbonei*	+			1,000
Mantellidae				
Aglyptodactylus madagascariensis	+	+	+	650-1,200
Aglyptodactylus securifer		+	+	400-650
Blommersia wittei	+	+	+	300-1,000
Boophis baetkei			+	400-500
Boophis blommersae	+	+		650-1,050
Boophis brachychir			+	400-500
Boophis septentrionalis	+	+	+	650-1,150
Boophis sp. nov. aff. *brachychir*	+		+	650-1,050
Boophis sp. nov. aff. *madagascariensis* "north"	+	+	+	500-1,050
Boophis tephraeomystax	+	+	+	100-1,000
Gephyromantis ambohitra	+			900-1,050
Gephyromantis granulatus	+	+	+	400-1,250
Gephyromantis cf. *horridus*	+			1,000-1,200
Gephyromantis pseudoasper	+	+	+	400-900
Guibemantis aff. *bicalcaratus*	+			950-1,200
Guibemantis liber	+			1,000-1,150
Mantella viridis			+	100-200
Mantidactylus ambreensis	+	+	+	400-1,150
Mantidactylus bellyi	+	+	+	400-1,150
Mantidactylus aff. *betsileanus*	+		+	450-1,050
Mantidactylus femoralis	+			650-1,150
Ptychadenidae				
Ptychadena mascareniensis	+	+	+	100-1,200
Reptilia				
Chamaeleonidae				
Brookesia ambreensis	+			650-1,050
Brookesia antakarana	+			650-1,050
Brookesia ebenaui	+	+	+	400-800
Brookesia sp. nov.			+	400-500
Brookesia stumpffi	+	+	+	400-1,200
Brookesia tuberculata	+			900-1,100
Calumma amber	+			900-1,300
Calumma ambreense	+			900-1,250
Calumma boettgeri	+			650-1,250
Calumma nasutum	+			900
Furcifer oustaleti		+	+	400-650
Furcifer pardalis	+	+	+	400-900
Furcifer petteri	+	+	+	400-700
Furcifer sp. nov.	+			800-900
Gekkonidae				
Blaesodactylus boivini			+	400-600
Ebenavia inunguis	+			650

Geckolepis cf. *maculata*	+	+	+	400-650
Hemidactylus frenatus			+	100-400
Lygodactylus madagascariensis	+	+		650-1,200
Lygodactylus cf. *heterurus*			+	100-200
Paroedura cf. *gracilis*	+			850-900
Paroedura cf. *oviceps*	+		+	400-800
Paroedura stumpffi	+	+	+	400-700
Phelsuma abbotti chekei			+	400-500
Phelsuma grandis	+	+	+	400-900
Phelsuma lineata dorsivittata	+	+	+	500-1,100
Uroplatus alluaudi	+		+	750-950
Uroplatus giganteus	+	+	+	400-850
Uroplatus sp. nov. aff. *henkeli*		+	+	400-650
Uroplatus sikorae	+		+	650-1,000
Uroplatus sp. nov. aff. *ebenaui*	+		+	400-1,200
Gerrhosauridae				
Zonosaurus haraldmeieri	+	+	+	400-1,000
Scincidae				
Amphiglossus alluaudi	+			?
Amphiglossus mandokava	+			950
Amphiglossus melanurus	+			1'100
Madascincus melanopleura	+			900-1,250
Madascincus mouroundavae	+			900-1,250
Madascincus cf. *polleni*	+		+	400-650
Paracontias brocchii	+			900-1,250
Paracontias hildebrandti	+			600-700
Trachylepis elegans	+	+	+	300-850
Trachylepis tavaratra			+	300-500
Boidae				
Sanzinia madagascariensis volontany	+	+	+	400-950
Colubridae sensu lato				
Alluaudina bellyi	+	+	+	400-650
Compsophis albiventris	+			900-1,250
Compsophis infralineatus	+			650
Dromicodryas quadrilineatus			+	400-500
Exallodontophis albignaci	+			650
Ithycyphus miniatus			+	400-500
Leioheterodon madagascariensis	+	+	+	100-1,000
Leioheterodon modestus		+	+	400-650
Liophidium rhodogaster	+			850-1,150
Liophidium sp.	+			650
Liophidium torquatum	+	+	+	400-950
Liopholidophis dimorphus	+			800-900
Mimophis mahfalensis			+	400-500
Pseudoxyrhopus ambreensis	+			900-1,200
Pseudoxyrhopus cf. *quinquelineatus*			+	?
Pseudoxyrhopus microps	+	+	+	500-650
Stenophis granuliceps	+	+	+	400-800
Stenophis inopinae			+	400-500
Stenophis cf. *variabilis*	+	+	+	400-800
Thamnosophis lateralis	+		+	300-900
Thamnosophis martae			+	400-500
Typhlopidae				
Typhlops microcephalus	+			650-1,200
Typhlops cf. *mucronatus*	+			650
TOTAL	75	36	59	-

of herpetological conservation importance. Due to its isolation from the rest of the eastern rainforest belt and the forests of the Sambirano region, the humid lowland rainforest and transitional forest of the Forêt d'Ambre may have served as a biological refuge. Therefore it may have preserved relict populations of species that disappeared from other regions of the eastern rainforest belt during dry periods; or it may have facilitated speciation through geographic isolation (Raxworthy and Nussbaum 1994). Both of these factors would have produced endemics in the Forêt d'Ambre forest and therefore this reserve may contain species that are found nowhere else (Köhler et al. 2008).

With regards to habitat quality, approximately half of all the species were only observed in relatively undisturbed forest which highlights the conservation importance of this habitat (Table 1). Only approximately one quarter of the species were observed in both forest and anthropogenically disturbed habitat which indicates that these species are able to adapt to adverse human activities to at least some degree. The remaining species were only observed in anthropogenically disturbed habitat. It is possible that this is because these particular habitats suit their needs or because they are indifferent to habitat change. However, it is also possible that this is because there are specific aspects of their natural history (i.e. nocturnal, cryptic behavior) that makes them difficult to observe in the more structurally diverse forest habitat.

The relatively large elevational range within the Montagne d'Ambre complex (Forêt d'Ambre Special Reserve, Montagne d'Ambre National Park and the Fontenay Nature Park) makes it an interesting area in Madagascar to study elevational influences on patterns of species distribution. It is also crucial for future conservation initiatives focusing on this area that this ecological aspect is characterized to enable informed decisions. The transitional 900 m contour observed for many species corresponds closely to the transition between lowland rainforest and moist montane rainforest, which is indicated by White (1983) to be about 800 m. The fauna of Forêt d'Ambre therefore appears to be largely composed of lowland rainforest species and some species that are also able to adapt to moist montane forest conditions found at the upper altitudes of the reserve.

RANGE EXTENSIONS This is the first published survey to focus on this area. Consequently most of the species found were new records for this specific locality. However, several species encountered during this study require special mention as their occurrence in the Forêt d'Ambre significantly contributes to the current information regarding their distribution in Madagascar. The presence of *Mantella viridis* at this locality is noteworthy because this species, until recently considered as critically endangered [now changed to endangered by Andreone et al. (2008a)], was only known from few localities in the extreme north of Madagascar (Glaw and Vences 2007). Similarly, prior to this survey the Colubrid snake *Thamnosophis martae* was only known from Montagne des Français. The Giant leaf-tailed gecko *Uroplatus giganteus* is also recorded from this reserve for the first time. This species is the second largest extant gecko in the world and is currently considered to be at serious conservation risk as a result of its limited distribution which is believed to be restricted to the Montagne d'Ambre mountain range (Glaw et al. 2006). This survey also extends the known habitat for several species that are more typically associated with dry deciduous forest: *Blaesodactylus boivini*, *Leioheterodon modestus*, *Phelsuma abbotti* and *Stenophis inopinae*.

MONTAGNE D'AMBRE The species accumulation curves for Forêt d'Ambre (Figure 2) indicate that this rapid assessment (12 days of research) was not enough to allow for complete sampling at this location. In contrast, the herpetofauna of Montagne d'Ambre National Park has been surveyed intensively by different researchers since long (Mocquard 1895, Ramanantsoa 1974, Andreone 1991, Glaw and Vences 1994, 2007, Raxworthy and Nussbaum 1994). It is therefore remarkable that several species have also been discovered in this reserve only recently, including *Boophis tephraeomystax*, *Mantidactylus* aff. *betsileanus*, *Furcifer* sp. nov., *Paroedura* cf. *gracilis*, *Amphiglossus mandokava*, and *Stenophis granuliceps*. These findings indicate that even intensive surveys, conducted by numerous researchers using different methods may often fail to obtain a complete herpetofaunal species inventory in rainforest areas of Madagascar which usually harbour a large amount of species.

ANTHROPOGENIC THREATS Socio-economic factors such as rapid population growth, poor education and other particular aspects of Malagasy culture are partly responsible for obliging local residents to employ harmful agricultural methods and other activities that lead to the exploitation of natural resources (Durbin et al. 2003) which can be a serious threat to amphibians and reptiles (Glaw and Vences 2007). As a result of its close proximity to the administrative capital of the Antsiranana province (ca. 30 km) and neighbouring communes such as Sakaramy and Joffreville, the unique biodiversity of this Special Reserve is particularly vulnerable to these anthropogenic pressures.

Indeed, our study revealed that the unique fauna of the Forêt d'Ambre is under immediate threat from numerous anthropogenic pressures that are currently being conducted within the Special Reserve despite its protective status. The major threats to the integrity of the herpetofauna of this area are: (1) agricultural clearance for banana, coffee, khat, maize, papaya, and rice cultivation; (2) charcoal production; (3) timber production; (4) small scale quarrying; and (5) zebu grazing (Figure 4 Plate A-D). Sites are either selectively logged or cleared of all trees as a result of all of these practices which has resulted in the degradation or clearance of large areas of forest within the reserve. In addition, other vertebrate groups within this Special Reserve are also under threat from subsistence hunting (researchers observed poachers with rifles targeting wetland bird species at Lac Mahery) and from feral cats and dogs, which were encountered on several occasions. Although illegal collection of reptiles and amphibians for the pet trade may have been taken place at this locality no evidence was gathered during this study.

These pressures on natural resources have already had a major impact at a national level [Myers et al. (2000) estimated that more than 90 % of the original natural vegetation has already been lost in Madagascar] and are currently believed to constitute the most severe threat to reptiles and amphibians in Madagascar (Vallan 2002, 2003, Andreone et al. 2005, 2008b, Glaw and Vences 2007). Continued forest clearance will lead to the eventual fragmentation of the remaining areas of forest (with serious consequences on herpetofauna, e.g. Vallan 2000), followed by local and possibly complete extinctions that will in turn place increased pressure on the existing system of protected areas in the north of Madagascar.

Plate A Plate B Plate C Plate D

FIGURE 4. Photographic documenation of clearings, plantations and other threats in Forêt d'Ambre.

Plate A: Banana plantation within the Forêt d'Ambre Special Reserve; Plate B: Agricultural clearance (for rice) within the Forêt d'Ambre Special Reserve; Plate C: Timber production within the Forêt d'Ambre Special Reserve; Plate D: Zebu grazing within the Forêt d'Ambre Special Reserve

EXISTING CONSERVATION INITIATIVES The extreme north of Madagascar is already recognized as one of the richest regions of the biodiversity hotspot that is Madagascar (e.g. Raxworthy and Nussbaum 1994, 1995, Andreone et al. 2003, Wilmé et al. 2006). In addition to the Montagne d'Ambre complex, this region contains five other major localized areas of forest (Analamera, Ankarana, Daraina, Montagne des Français and Orangea) and a plethora of much smaller more fragmented areas (e.g. Ampombofofo, Manondro, Nosy Hara, Windsor Castle). In order to protect these unique habitats from the anthropogenic threats highlighted above, existing conservation strategies are in place, which include the identification of priority areas in Madagascar for threatened or overall species diversity and their inclusion in protected nature reserves (Ganzhorn et al. 1997, ANGAP 2001, Kremen et al. 2008).

In theory these protected nature reserves are an effective means to protect tropical biodiversity and they can be successful at stopping land clearing, and to a lesser degree effective at mitigating logging, hunting, fire, and grazing (Bruner et al. 2001). However, it has also been demonstrated that their effectiveness correlates with basic management activities such as enforcement, boundary demarcation, and direct compensation to local communities (Bruner et al. 2001), which require substantial financial investment (Balmford and Whitten 2003). Furthermore, in practice the identification and management of priority areas has also been constrained by lack of information on the distribution, abundance, and habitat requirements of threatened species and the size, condition, and threats to survival of forest remnants (Smith et al. 1997). This type of baseline information is needed to integrate information relevant to existing conservation and development programmes and guide the course of future management strategies (Kremen et al. 1994). There is a distinct lack of funding and baseline biodiversity data for the majority of protected and non protected areas of forest in Madagascar which may explain the current situation at the Forêt d'Ambre Special Reserve.

Internationally, in the past three decades conservation biologists have developed powerful tools for reserve selection and design (Kremen et al. 1999, 2008). Using fundamental biological and socioeconomic principles of modern conservation science, complex park proposals and management plans are developed that are specifically designed to balance human and wildlife needs (Kremen et al. 1994). Created and relatively neglected since 1958, it is likely that the Reserve was not designed with the aim of preserving natural resources and biodiversity in concert with improving human well-being or the importance of the consent and support of local inhabitants (Kremen et al.1994). Furthermore it is also possible that the integrity of the biodiversity within the Forêt d'Ambre Special Reserve has also suffered as a result of its close proximity to the Montagne d'Ambre National Park. With limited funding and manpower it appears that ANGAP and previous management authorities have focused on the biodiversity in the moist montane forest found at the higher elevations.

FUTURE CONSERVATION INITIATIVES It is clear that immediate increased conservation management action is required to protect the biological diversity found within the Forêt d'Ambre Special Reserve. We strongly suggest that this should be made effective immediately because of the relatively small surface area (4,810 ha) of this special reserve and the frequency and intensity of which anthropogenic disturbance was encountered during this survey. We predict that without immediate action the majority of the habitat in this Special Reserve will be subject to some form of adverse anthropogenic activity within the next five to 10 years. Based on the findings of this survey we provide conservation recommendations for this highly diverse site of herpetological importance:

- Establishment of an enforcement training programme which will produce forest wardens that will be able to patrol the existing core protected area and act as an active deterrent.
- Further assessment and monitoring of natural resource use activities. In particular, clearance of forest needs to be restricted and the remaining areas must be carefully monitored (e.g. by remote sensing using satellite data).
- Development of small scale eco-tourism (such as that employed at the Montagne d'Ambre National Park) as a workable alternative to non-sustainable resource use. Attractions and activities could include guided walks, boat trips and the utilization of specially designed bird hides.
- Development and implementation of a large-scale, regionally connected, more sustainable community-focused management system, which includes payments for ecosystem services, including biodiversity conservation and carbon sequestration.
- Development efforts, to promote sustainable agriculture practices and to improve human conditions. Village-based education programmes aimed at demonstrating alternative energy systems and crops, which are compatible with local traditions.

- Raising awareness about environmental problems. Village-based programmes targeting all socioeconomic groups.
- Implementation of additional biodiversity surveys focused on the other major taxonomic groups found within the Forêt d'Ambre Special Reserve.
- Implementation of additional biodiversity surveys in the remaining protected areas in the Antsiranana Province.

ACKNOWLEDGEMENTS

We thank Parfait Bora, Hildegard Enting, Angelika Knoll, Zoltan Nagy, Marta Puente, Angelin and Angeluc Razafimanantsoa for their help in the field. We are very grateful to the Fontenay team (Raymond, Marie-José, Karl-Heinz) for their great hospitality and support during our fieldwork. The work was carried out in collaboration with the Département de Biologie Animale, Université d'Antananarivo, and the Association Nationale pour la Gestion des Aires Protégées (ANGAP). We are grateful to the Malagasy authorities, in particular the Ministère de l'Environnement et des Eaux et Forêts, for research and export permits. This survey was made possible by financial support of 'Act for Nature' and the engagement of his president, Olivier Arnoult, and the European Association of Zoos and Aquaria (EAZA). We also thank Paul Alibert and Jeremy Sabel for assisting with the provision of a French translation of the abstract.

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APPENDIX I

Voucher specimens from Forêt d'Ambre Special Reserve (including Lac Mahery) and Le Fontenay Nature Park in alphabetical order:

Aglyptodactylus securifer UADBA (FGZC 1378, 1699, 3103), ZSM 2159/2007, 2231/2007, 1633-1635/2008; *Alluaudina bellyi* ZSM 1626/2008; *Blommersia wittei* UADBA (FGZC 3137, 3139-3141), ZSM 2229/2007, 1657-1658/2008; *Boophis blommersae* UADBA (FGZC 1865); *Boophis brachychir* UADBA (FGZC 1379, 1388, 1392), ZSM 2155-2157/2007, 2227-2228/2007, 2230/2007; 1641-1642/2008; *Boophis septentrionalis* ZSM 2158/2007; *Boophis tephraeomystax* ZSM 1643-1644/2008; *Boophis baetkei* ZSM 2051/2007, 1638/2008; *Boophis* sp. nov. aff. *brachychir* ZSM 1639-1640/2008; *Boophis* sp. nov. aff. *madagascariensis* «north» UADBA (FGZC 3130, 3132); *Brookesia* sp. nov. UADBA (FGZC 1255-1257, 1259, 1261-1262, 1264, 1266-1268, 1700, 1879, 3112), ZSM 2170-2179/2007, 1506/2008; *Brookesia stumpffi* UADBA (FGZC 1233, 1236-1239, 3113), ZSM 2165-2166/2007; *Cophyla* sp. nov. ZSM 1659/2008; *Furcifer petteri* UADBA (FGZC 1224, 1225), ZSM 2160-2161/2007; *Geckolepis* cf. *maculata* UADBA (FGZC 1231, 3122), ZSM 2164/2007, 1520/2008; *Gephyromantis pseudoasper* ZSM 1651/2008; *Hemidactylus frenatus* ZSM 1533/2008; *Lygodactylus* sp. ZSM 1542/2008; *Madascincus* cf. *polleni* UADBA (FGZC 3123), ZSM 2162/2007, 1558/2008; *Mantella viridis* ZSM (FGZC 3155); *Mantidactylus ambreensis* ZSM 1653/2008; *Mantidactylus bellyi* UADBA (FGZC 1217, 1382, 1384, 3109, 3146-3149, 3159), ZSM 2224-2226/2007, 1652/2008; *Mantidactylus* aff. *betsileanus* UADBA (FGZC 1377); *Paroedura* cf. *oviceps* ZSM 1527/2008; *Paroedura stumpffi* UADBA (FGZC 3118), ZSM 2163/2007, 1526/2008; *Phelsuma abbotti chekei* ZSM (FGZC 3143); *Phelsuma lineata dorsivittata* UADBA (FGZC 3144); *Pseudoxyrhopus* cf. *ambreensis* UADBA (FGZC 3157); *Pseudoxyrhopus microps* ZSM 1611/2008; *Pseudoxyrhopus* cf. *quinquelineatus* ZSM 1608/2008; *Rhombophryne* sp. nov. UADBA (FGZC 1890, 1891), ZSM 1628-1629/2008; *Stenophis granuliceps* UADBA (FGZC 1229); *Stenophis inopinae* ZSM 1603/2008; *Stenophis* cf. *variabilis* ZSM 1605/2008; *Stumpffia* sp. UADBA (FGZC 1689, 3104-3105, 3152), ZSM 1670/2008; *Thamnosophis lateralis* UADBA (FGZC 1696, 3150), ZSM 1600/2008; *Thamnosophis martae* ZSM 2062/2007, 1597/2008; *Trachylepis tavaratra* UADBA (FGZC 3133, 3135), ZSM 1551/2008; *Uroplatus* sp. nov. aff. *ebenaui* ZSM (FGZC 1876, 3116, 3153); *Uroplatus giganteus* ZSM (FGZC 3165); *Uroplatus* aff. *henkeli* UADBA (FGZC 3107), ZSM (FGZC 3117); *Uroplatus sikorae* UADBA (FGZC 3151); *Zonosaurus haraldmeieri* UADBA (FGZC 3110), ZSM 1501-1502/2008.

Conservation status of vascular plant species from the QMM / Rio Tinto mining area at Mandena, Tolagnaro (Fort Dauphin) region,southeast Madagascar

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ABSTRACT

A botanical inventory of the Mandena littoral forest, completed in 1991 as part of an environmental impact assessment study for a titanium oxide mining project being developed by QMM / Rio Tinto in the Tolagnaro (Fort Dauphin) region of southeastern Madagascar, identified 29 plant taxa as priorities for conservation, including 16 known only from the proposed mining path (Priority 1) and 13 restricted to the exploration zone (Priority 2). A re-evaluation in 2001 added 11 taxa from Mandena (the first of three sites targeted for mining, to be followed later by Petriky and then Sainte Luce) and removed 13 others, leaving a total of 27 taxa, five classified as Priority 1 and 22 as Priority 2. Using currently available data, we have removed four additional taxa from the list (three because populations were found outside the Tolagnaro area and one because it's earlier inclusion on the list had been in error) and transferred four others from Priority 1 to Priority 2 as populations had been located within one or more of the newly-established conservation zones at Sainte Luce (747 ha), Mandena (230 ha) and Petriky (125 ha). Of the 15 currently recognized priority taxa present at Mandena, only two (an undescribed species in each of the genera *Canthium* and *Pseudocatha*) appear to be endemic there, but all remain a focus of QMM's environment, conservation and restoration activities. A total of 15 Mandena taxa are listed as threatened on the 2008 IUCN Red List (3 Critically Endangered, 7 Endangered, and 5 Vulnerable), most of which must be regarded as important for conservation; only three of these taxa also appear on the priority list, and none of the 12 remaining priority taxa from Mandena have been assessed for the Red List, underscoring the urgent need to expand evaluation to encompass the entire Malagasy flora and in particular range-restricted taxa.

RÉSUMÉ

Un inventaire botanique de la forêt littorale de Mandena, clôturé en 1991 dans le cadre d'une étude d'impact environnemental portant sur un projet d'extraction minière d'oxyde de titane élaboré par QMM / Rio Tinto dans la région de Tolagnaro (Fort-Dauphin) au sud-est de Madagascar, a identifié 29 taxons de plantes prioritaires en matière de conservation, dont 16 taxons qui n'étaient connus que des seules parcelles à exploiter (Priorité 1) et 13 taxons dont la distribution était limitée à la zone d'exploration (Priorité 2). Une nouvelle évaluation en 2001 ajouta 11 taxons de Mandena (premier site qui fera l'objet de l'exploitation minière et qui sera suivi par Petriky puis Sainte Luce) et retira 13 autres taxons, ramenant ainsi la liste à 27 taxons dont cinq taxons de Priorité 1 et 22 de Priorité 2. En considérant les données actuellement disponibles, nous avons retiré quatre autres taxons de la liste (trois taxons pour lesquels des populations ont été localisées au-delà de la région de Tolagnaro et un dernier taxon car son inclusion initiale sur la liste n'était pas justifiée) et en avons déclassé quatre autres taxons en les passant de Priorité 1 à Priorité 2 avec des populations identifiées dans une ou plusieurs zone(s) de conservation nouvellement mise(s) en place à Sainte Luce (747 ha), Mandena (230 ha) et Petriky (125 ha). Sur les 15 taxons prioritaires actuellement reconnus et qui sont rencontrés à Mandena, seulement deux (une espèce non décrite dans chacun des genres *Canthium* et *Pseudocatha*) semblent y être endémiques mais tous sont concernés par les activités environnementales, de conservation et de restauration de QMM. Quinze taxons de Mandena figurent sur la Liste Rouge des espèces menacées 2008 de l'UICN (3 'en danger critique d'extinction', 7 'en danger' et 5 'vulnérable') dont la plupart doivent être considérés comme importants pour la conservation ; seuls trois de ces taxons apparaissent également sur la liste prioritaire alors qu'aucun des 12 autres taxons prioritaires de Mandena n'a été évalué pour la Liste Rouge, soulignant ainsi le besoin urgent d'étendre l'évaluation pour inclure l'ensemble de la flore malgache et plus particulièrement les taxons avec des distributions réduites.

KEYWORDS: IUCN Red List, littoral forest, plants, priority species, QMM / Rio Tinto.

INTRODUCTION

The Mandena forest, located ca. 10 km NNE of Tolagnaro (Fort Dauphin) in southeastern Madagascar (for example Figure 1), has been the subject of botanical inventory work since the 1950s, when a forestry station was established and agents

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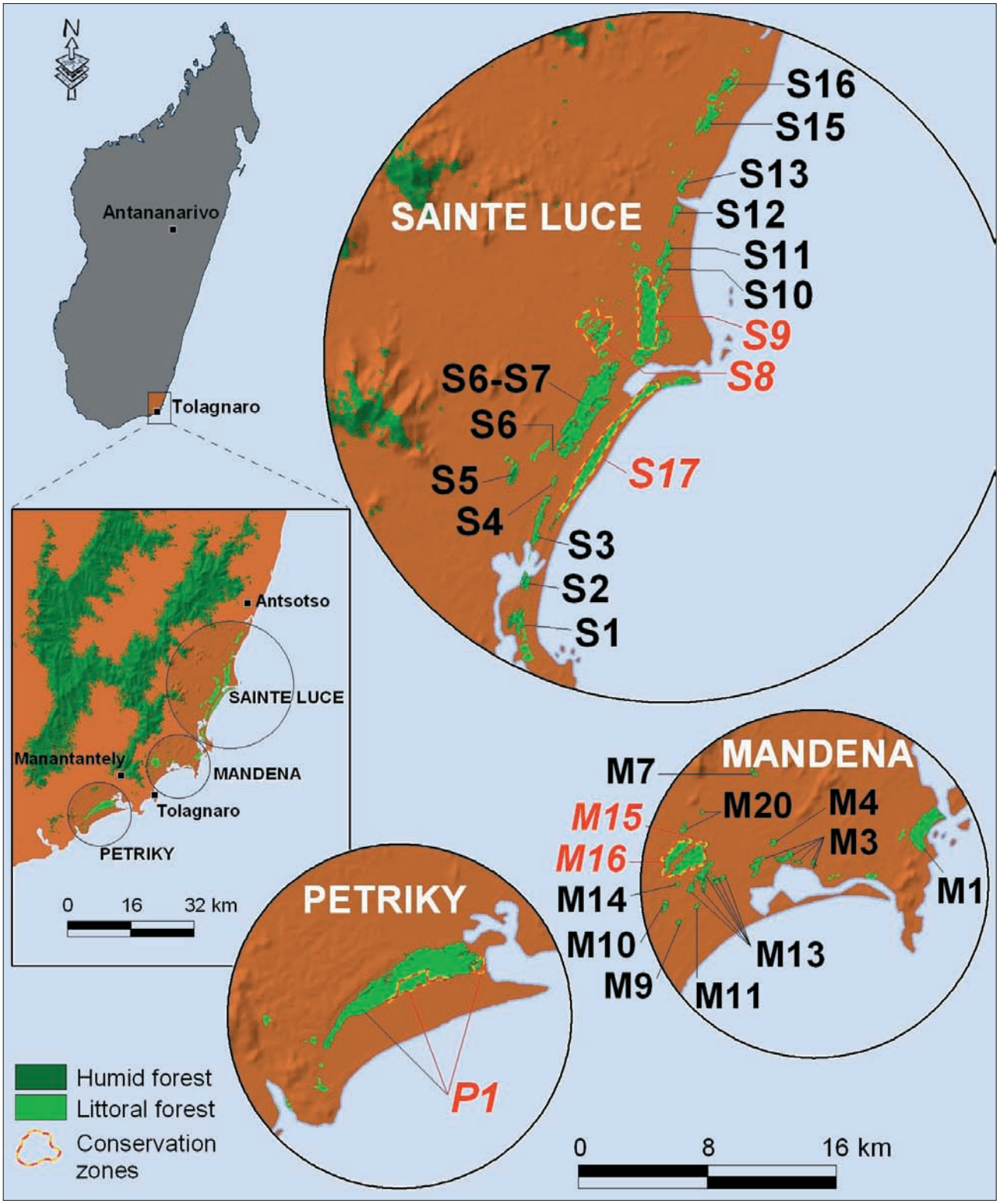

FIGURE 1. Map of the Sainte Luce, Mandena and Petriky areas in southeast Madagascar, indicating the location of major littoral forest parcels (light green), including those that comprise the newly-established conservation zones at the three sites (dashed red and yellow lines).

began collecting specimens as part of an effort to document the island's woody plants in a new herbarium that had recently been established in Antananarivo by forest botanist René Capuron. Over the following three decades, approximately 500 plant collections were made at Mandena, several of which represented species new to science, and Capuron himself visited the site on at least four occasions.

Starting in 1986, QIT Madagascar Minerals (QMM) began an extensive exploration program along the eastern coast of Madagascar to locate deposits of heavy mineral sands containing titanium dioxide. Major mineral sediments were found at Mandena, Sainte Luce, and Petriky (for example Figure 1, 2) underneath southeastern Madagascar's largest remaining stands of littoral forest, a distinctive type of humid evergreen

forest restricted to unconsolidated sand within a few kilometers of the Indian Ocean (Vincelette et al. 2003 and 2007a, Consiglio et al. 2006, Rabenantoandro et al. 2007). As the mining project was developed, a series of studies commissioned by QMM clearly demonstrated the importance of the region's biodiversity and identified many issues with ramifications for environmental conservation (Ganzhorn et al. 2007). In late 2003, Rio Tinto, which had previously acquired QMM, provided further support to addressing biodiversity issues in the Tolagnaro region with the promulgation of its Biodiversity Strategy and Guidelines (Rio Tinto 2004), officially launched in November 2004 during the IUCN World Conservation Congress in Bangkok, Thailand.

As part of QMM's initial environmental impact assessment conducted in the late 1980s and early 1990s, a preliminary study was undertaken to document the flora of the littoral forests of the Tolagnaro region and to identify plant species (and infraspecific taxa) that might be endemic to these forests and whose continued survival might thus be placed at risk by the mining operation. Using data gathered in the field by a team of experienced botanists as part of an extensive botanical inventory of the Sainte Luce, Mandena and Petriky sites (an ongoing endeavor that to date has generated more than 1,500 additional collections) supplemented with information from the available literature and specimens deposited in the major herbaria containing collections of Malagasy plants (within Madagascar as well as in France and the USA), a list was compiled of plant taxa that had been documented from one or more of the three sites but were not known from recent specimens made elsewhere. This list was presented in an unpublished technical report (Lowry 1991) that comprised part of QMM's initial environmental impact assessment. Each taxon on this list of potential 'priority plant species for conservation' was classified into one of two categories:

- Priority 1: taxa known only from the planned mining path at Sainte Luce, Mandena and Petriky
- Priority 2: taxa restricted to the QMM mine exploration zone

The original list comprised a total of 29 priority taxa, 16 classified as Priority 1 taxa and 13 as Priority 2 taxa (Lowry 1991). These became one of the primary foci of QMM's *in-situ* and *ex-situ* propagation and conservation activities (Vincelette et al. 2007b) and were the target of intensive field studies to learn more about the distribution, ecology and biology of these species in an effort to ensure that the mining company would be able to implement appropriate measures to ensure their long term survival (see for example Randriatafika et al. 2007). Protection of the priority taxa also provided a major impetus for the establishment in 2000 of a 230 ha community-managed conservation zone at Mandena comprising parcels M15 and M16 (for example Figure 1) and formally incorporated into Madagascar's growing network of protected areas in 2008. A conservation zone was also established at Sainte Luce in 2005 encompassing 747 ha of forest and wetland, and 125 ha were included in a conservation zone at Petriky in 2008 (Vincelette et al. 2007a and 2007c).

When QMM's revised environmental and social impact assessment was conducted in 2001, the original list of priority plants provided a decade earlier by Lowry (1991) was re-evaluated and updated in a second unpublished report (Lowry 2001). The process of updating the list involved the following aspects:

- Taxa on the initial 1991 list were re-examined with regard to their presence within each of the three planned mining zones (Sainte Luce, Mandena and Petriky) rather than collectively for the three sites as in the initial study.
- Taxa were evaluated with respect to the IUCN Red List criteria (IUCN 2001) in an effort to ensure that consideration was given to all taxa that were potentially threatened or otherwise of conservation concern.
- Taxa that had been added to the overall floristic list in the decade between 1991 and 2001 were examined using the same criteria as those applied by Lowry (1991) and were included on the revised list of priority plant taxa as appropriate.
- New collections made between 1991 and 2001 of taxa on the original priority list were recorded and the list was updated accordingly.

Analysis of the updated information resulted in a revised list that included a total of 27 priority taxa, five of which were classified as Priority 1 taxa and 22 as Priority 2 taxa (as reported by Lowry 2001). Since then, all of these priority taxa have remained a focus of QMM's environment, conservation and restoration activities. However, as exploitation will first begin in the Mandena zone in late 2008, the status of the priority taxa known from this site is of the most immediate concern. In this paper we re-examine and update the status of the priority taxa for conservation occurring at Mandena.

METHODS

In order to identify Priority 1 and Priority 2 taxa at Mandena we first generated a list of all plants recorded from the area by consulting two key sources. The TROPICOS database (Missouri Botanical Garden-a) is the world's largest and most comprehensive source of botanical data, containing extensive information on the Malagasy flora, including all data gathered as part of the flora and vegetation component of the QMM environmental impact assessment study, supplemented with information on more recent collections made in the region and in other littoral forest sites along Madagascar's east coast (see Consiglio et al. 2006) as well as on Malagasy species recently described as new to science. The SONNERAT database (Muséum National d'Histoire Naturelle) contains extensive records of collections from Madagascar along with digitized images of thousands of type specimens, many of which are not represented in other herbaria. Data from these two sources were combined, checked and corrected as necessary to generate a comprehensive list of all taxa recorded from Mandena.

Using this updated floristic list, data were then examined to determine which taxa are widely distributed within Madagascar and / or have been documented from outside the Tolagnaro region during the last 20 years. These taxa, whose continued survival is not directly threatened by the mining operation, were excluded from further consideration as potential local endemics. The remaining taxa were regarded as possibly endemic to the Mandena area and therefore potentially at risk and candidates for Priority 1 or Priority 2 status. Recently published taxonomic works were consulted to extract relevant information that had not yet been captured into the TROPICOS or SONNERAT databases. We also examined the field books of botanists who had recently collected in the Tolagnaro region for additional informa-

FIGURE 2: Littoral forest at Petriky, southeast of Tolagnaro (Fort Dauphin), where many QMM priority plant species occur, including eight that are shared with Mandena. The road on the right of the image was opened in the mid-1980s to provide access for QMM's exploration work (Photo: J. Rabenantoandro/QMM).

tion. The data obtained through these steps were compiled in an 'endemic species data file', which has been kept up-to-date as new information has become available.

The list of taxa in the data file was then compared with the 1991 list of priority taxa in order to identify those whose status had changed as a result of information that had become available in the intervening years. Taxa that had originally met the criteria for Priority 1 or Priority 2 status in 1991 but no longer did were noted, and the reasons for their change in status were recorded. Examples of such changes in status include broadened species circumscriptions that encompassed populations from other parts of Madagascar and the discovery of populations at sites within the Tolagnaro region but outside the mine exploration zone. Information on taxa belonging to groups currently being studied was solicited from specialists and was included in the re-evaluation of species whenever possible.

We then reviewed data on all Malagasy plant species on the IUCN Red List (IUCN 2008) and noted those recorded from the Mandena area. Because Red Listed taxa are widely regarded as of potential conservation concern, all those present at Mandena were included in the data file, regardless of whether they were considered to be endemic there or whether they met the criteria for Priority 1 or Priority 2 status. Botanists conducting taxonomic research on various Malagasy plant groups were also consulted to determine whether they knew of any species that they regarded as potentially endemic to the Mandena area but had not previously been classified as priority taxa or included in the endemic species data file. These taxa were likewise added to the data file.

In order to facilitate fieldwork by QMM staff conducted as part of a program to locate and identify populations of taxa in the endemic species data file, a field guide was compiled containing detailed information on each taxon, including collection records with geographic coordinates, scanned images and drawings, species descriptions, and notes provided by specialists (when available). An intensive campaign of fieldwork was conducted between July 2000 and February 2001 in areas outside the Mandena zone and beyond the limits of the proposed mining path to locate populations of the species listed in the data file from new localities where their presence had not previously been recorded. Each new population was documented using the same standard techniques (Missouri Botanical Garden-b) that had previously been used for the flora and vegetation environmental impact assessment study and subsequent fieldwork. The information obtained was used to update the list of priority species, as reported by Lowry (2001). Fieldwork has continued since then and relevant data have systematically been entered into the endemic species data file.

Finally, the information contained in the endemic species data file was incorporated into a GIS and was used to map each taxon in order to conduct a visual evaluation of its geographic distribution, and to confirm whether any populations had been recorded within the previous 20 years outside the mine exploration area or whether the taxon must be regarded as endemic to Mandena. The results of these analyses were used to generate a revised list of Priority 1 and Priority 2 taxa using the criteria indicated above.

RESULTS

The current revised and updated floristic list for the Mandena area contains a total of 414 species of vascular plants (see Rabenantoandro et al. 2007 for a complete listing). This list is not definitive and will in all likelihood change with new identifications and additional fieldwork. It does, however, accurately reflect the current state of knowledge of the area's flora as of late 2007.

Table 1 lists the 40 taxa recorded within the QMM mining area (Sainte Luce, Mandena and Petriky) that have at one time or another been regarded as Priority 1 or Priority 2 taxa (see Figures 3, 4, 5, 6 for example). These include the 29 taxa on the original 1991 priority species list (Lowry 1991) along with 11 taxa from Mandena that were added to the list in the 2001 update (Lowry 2001).

TABLE 1. List of the 29 priority plant taxa identified for the 1991 QMM environmental impact assessment and the 11 priority taxa from Mandena added in 2001, with their current (2008) status along with the reasons for changes in status, additions and removals from the list.

Taxon (as indicated in the 1991 flora study and / or the 2001 update)	Family	Priority category in 1991 list	Priority category in 2001 list	Current prioritiy category in 2008	Known from Mandena	Reason of change in priority category (if any) or addition to removal from priority taxon list
Asteropeia micraster Hallier f.	Asteropeiaceae	Not listed	2	Not listed	+	Species limits recently revised by specialists; found at Mahabo outside the Tolagnaro region
Astrotrichilia elliotii (Harms) Cheek	Meliaceae	1	2	2	+	Found in the Mandena conservation zone (M15), in parcel M7 (off mine path), and in Petriky; probably occurs elsewhere in Madagascar but not recently documented
Apodytes sp. nov.	Icacinaceae	2	Not listed	Not listed	+	Found at Antsotso outside the Tolagnaro region; recently described as *A. bebile* Labat et al.
Canthium sp. nov.	Rubiaceae	Not listed	1	1	+	Species recently recognized by specialist (not yet published)
Capurodendron delphinense Aubrév.	Sapotaceae	2	2	2	-	Status unchanged, occurs at Petriky
Cissus leucophlea (Scott-Elliot) Suess.	Vitaceae	1	1	1	-	Status unchanged, occurs at Petriky
Croton louvelii Leandri	Euphorbiaceae	2	Not listed	Not listed	+	Specimens now placed in *C. daphnifolium* ined.
Croton trichotomus Geiseler var. *pulchellus* (Baill.) Leandri	Euphorbiaceae	Not listed	1	2	+	Specimens previously unidentified, found in the Petriky conservation zone
Cryptocarya elliotii Kosterm.	Lauraceae	1	1	1	-	Now included in *Aspidostemon parvifolium* (Scott-Elliot) van der Werff, which remains a Priority 1 taxon
Cynorkis elata Rolfe	Orchidaceae	1	2	2	+	Found in the Mandena conservation zone (M15), in parcel M7 (off mine path), and in the Sainte Luce conservation zone (S9)
Diphasia madagascariensis H. Perrier	Rutaceae	2	Not listed	Not listed	-	Taxon now placed in *Vepris madagascariens* (H. Perrier) Mziray; recent collections made outside the Tolagnaro region
Dombeya australis Scott-Elliot ssp. *australis*	Malvaceae s. lat.	1	Not listed	Not listed	+	Recent collections made outside the Tolagnaro region
Dombeya mandenensis Arènes	Malvaceae s. lat.	1	2	2	+	Found in the Mandena conservation zone (M15 & M16) and at Sainte Luce
Dracaena bakeri Scott-Elliot	Ruscaceae	1	2	2	+	Found in the Mandena conservation zone (M16)
Eligmocarpus cynometroides Capuron	Fabaceae	2	1	1	-	Populations from outside Petriky now extinct
Eugenia cloiselii H. Perrier	Myrtaceae	2	Not listed	Not listed	+	Recent collections made outside the Tolagnaro region
Eulophia palmicola H. Perrier	Orchidaceae	Not listed	2	Not listed	-	Not present at Mandena (collected in 1995 outside mine area at Nahampoina private reserve)
Euphorbia francoisii Leandri var. *francoisii*	Euphorbiaceae	Not listed	2	2	+	Specimens previously unidentified; found in the Mandena conservation zone (M15 & M16) and in the Petriky conservation zone
Euphorbia lophogona Lam.	Euphorbiaceae	Not listed	2	2	+	Specimens previously unidentified; found in the Mandena conservation zone (M15 & M16) and in the Sainte Luce conservation zone (S9)

TABLE 1. Continued

Taxon (as indicated in the 1991 flora study and / or the 2001 update)	Family	Priority category in 1991 list	Priority category in 2001 list	Current prioritiy category in 2008	Known from Mandena	Reason of change in priority category (if any) or addition to removal from priority taxon list
Kalanchoe rosei Raym.-Hamet & H. Perrier ssp. *serratifolia* Humbert	Crassulaceae	2	Not listed	Not listed	-	Now regarded as a hybrid and no longer considered a valid taxon
Leptolaena delphinensis G. E. Schatz & Lowry	Sarcolaenaceae	Not listed	2	2	+	Species recently described by specialists; found in the Mandena conservation zone (M15 & M16) and in the Sainte Luce conservation zone (S9)
Malleastrum mandenense J.-F. Leroy	Meliaceae	2	2	2	+	Found in the Mandena conservation zone (M15 & M16), in the Sainte Luce conservation zone (S9 and S17) and at Petriky
Meineckia websteri Brunel & J. Roux	Euphorbiaceae	1	1	1	-	Status unchanged; found in the Petriky conservation zone
Memecylon delphinense H. Perrier	Myrtaceae	1	Not listed	Not listed	+	Found at Antsotso outside the Tolagnaro region
Mollugo decandra Scott-Elliot	Mollugonaceae	2	Not listed	Not listed	-	Recent collections made outside the Tolagnaro region
Oncostemum dauphinense H. Perrier	Myrsinaceae	1	Not listed	Not listed	+	Found at Antsotso outside the Tolagnaro region
Ophiocolea delphinensis H. Perrier	Bignoniaceae	2	Not listed	Not listed	+	Found at Antsotso outside the Tolagnaro region
Pentarhopalopilia sp. nov.	Santalaceae	2	2	Not listed	+	Recently described as *Pilgerina madagascariensis* Z.S. Rogers et al., a new monotypic genus, and now known from outside the Tolagnaro region
Pentopetia boivinii Costantin & Gallaud	Apocynaceae	Not listed	1	Not listed	+	Specimens previously unidentified; found at Mahabo outside the olagnaro region
Phyllanthus cryptophilus (A. Juss.) Müll. Arg.	Phyllanthaceae	1	Not listed	Not listed	+	Recent collections made outside the Tolagnaro region
Polyalthia pendula Capuron ex G. E. Schatz & Le Thomas	Annonaceae	2	2	2	-	Status unchanged
Pseudocatha sp. nov.	Celastraceae	1	2	2	+	Found in the Mandena conservation zone (M16)
Pyrostria sp. nov.	Rubiaceae	Not listed	1	2	+	Species recently recognized by specialist (not yet published); found in Sainte Luce conservation zone (S8)
Secamone sp. nov.	Asclepiadaceae	1	1	2	+	Material from Mandena now identified as *S. humbertii* Choux, a Priority 2 taxon found in the Mandena conservation zone (M16) and the Petrky conservation zone
Stephanodaphne cremostachya Baill.	Thymelaeaceae	2	Not listed	Not listed	+	Found at Manantantely and on Pic Saint Jacques outside the Tolagnaro region
Tachiadenus longifolius Scott-Elliot	Gentianaceae	1	Not listed	Not listed	+	Found at Antsotso outside the Tolagnaro region
Talinella dauphinensis Scott-Elliot	Portulacaceae	1	Not listed	Not listed	-	Recent collections made elsewhere in Madagascar
Vitex bracteata Scott-Elliot	Lamiaceae	1	2	2	-	Occurs at Petriky only, incl. in conservation zone (incorrectly listed previously as present at Mandena)
Vitex grandidiana W. Piep.	Lamiaceae	Not listed	2	2	+	Specimens previously unidentified; found in the Mandena conservation zone (M15 & M16) and in the Sainte Luce conservation zone (S9)
Vitex tristis Scott-Elliot	Lamiaceae	Not listed	1	2	+	Specimens previously unidentified; found in swamp forest in the Mandena conservation zone (M15 & M16) and in the Sainte Luce conservation zone (S8 & S9)

Of the 29 priority taxa on the original 1991 list, a total of 14 were removed in 2001 (for example Table 1). Most of these (12 taxa) were taken off the list because populations were discovered at sites outside the mine area where they will not be directly threatened by the mining operation. In one instance, however, a species was removed because the collections of this taxon had been re-identified as a different, more widespread species that did not meet the criteria for Priority 1 or Priority 2 status. In the remaining case the taxon was found to be a hybrid and was therefore removed from the list.

Of the 15 priority taxa listed in 1991 that remained on the 2001 list (for example Table 1), eight were unchanged in status whereas six were transferred from Priority 1 to Priority 2 status, in each case because one or more populations were located within the parcels designated as the Mandena conservation zone (parcels M15 and M16) and / or in parcel M7 located outside the mine area (for example Figure 1). A single species, *Eligmocarpus cynometroides*, restricted to Petriky, was elevated from Priority 2 to Priority 1 status because the only known population from outside the Petriky area was extirpated.

The addition of 11 taxa from Mandena to the priority species list in 2001 (for example Table 1) was based on several considerations. Six priority taxa (three Priority 1 and three Priority 2) were represented among the herbarium material that was not fully identified until after completion of the 1991 report. Four more priority taxa (two Priority 1 and two Priority 2) were recognized as new by specialists in the course of preparing recently published taxonomic revisions (Schatz et al. 1999 and 2001) and ongoing research, and one additional Priority 2 taxon was documented for the first time in the decade prior to 2001.

The re-evaluation of the priority species conducted for the present analysis based on information gathered since 2001, resulted in changes in status for eight taxa (for example Table 1). Three of these taxa (*Asteropeia micraster*, a new species of *Pentarhopalopilia*, and *Pentopetia boivinii*) were removed from the list because populations were located outside the Tolagnaro region, and one taxon that had been added in 2001

FIGURE 3. Flowers of *Dombeya mandenensis* (Malvaceae sensu lato), a Priority 2 species known only from Mandena (where it occurs within the newly-established conservation zone, comprising parcels M15 & M16) and from Sainte Luce (Photo: D. Rabehevitra).

(*Eulophia palmicola*) was removed because it had been listed as occurring at Mandena by error. The four remaining taxa (*Croton trichotomus* var. *pulchellus*, *Vitex tristis*, and one new species in each of the genera *Pyrostria* and *Secamone*) were transferred from Priority 1 to Priority 2 status because continued fieldwork had led to the discovery of populations in the conservations zones at Sainte Luce, Mandena and/or Petriky.

Of the 29 priority taxa on the original 1991 list, 18 are known from Mandena (for example Table 1) but only one (a new species of *Pseudocatha*) appears to be endemic there, where it occurs within the Mandena conservation zone. Among the 11 priority taxa from Mandena added in 2001, none are endemic to the site.

Table 2 lists the 15 taxa present at Mandena that are classified as threatened on the most recent IUCN Red List (IUCN 2008). Three of these taxa have been assigned to the Critically Endangered (CR) category, seven are treated as Endangered (EN), and the remaining five are regarded as Vulnerable (VU). Only three of the 15 taxa classified as threatened based on the Red List criteria (two CR and one VU) qualify as Priority 2 species.

FIGURE 4

FIGURE 5

FIGURE 6

FIGURE 4. Fruit of *Malleastrum mandenense* (Meliaceae), another Priority 2 species, recorded from the conservation zones at both Sainte Luce and Mandena, as well as from Petriky (Photo: D. Rabehevitra).

FIGURE 5. Fruits of an undescribed species of *Pyrostria* (Priority 2) in the coffee family (Rubiaceae), restricted to Mandena and the conservation zone at Sainte Luce (parcel S8) (Photo: D. Rabehevitra).

FIGURE 6. Flowers of *Vitex grandidiana* (Lamiaceae), a Priority 2 species found in the conservation zone at Mandena (M15 & M16) and Sainte Luce (S9) (Photo: P. P. Lowry II).

TABLE 2. List of plant species recorded from the Mandena site listed as threatened on the 2008 IUCN Red List, along with their current (2008) status on the list of Priority 1 and Priority 2 taxa (CR = Critically Endangered; EN = Endangered; VU = Vulnerable).

Taxon	Family	IUCN threat status (criteria)	Priority category
Leptolaena delphinensis G. E. Schatz & Lowry	Sarcolaenaceae	CR (A3cd)	2
Beccariophoenix madagascariensis Jum. & H. Perrier	Arecaceae	CR (B1+2cd)	Not listed
*Euphorbia francoisi*i Leandri var. *francoisii*	Euphorbiaceae	CR (B1ab(iii,v))	2
Intsia bijuga (Colebr.) Kuntze	Fabaceae	EN (A1cd)	Not listed
Dalbergia maritima R. Vig.	Fabaceae	EN (A1cd+2cd)	Not listed
Dalbergia delphinensis Bosser & R. Rabev.	Fabaceae	EN (A2cd, B1+2bcde)	Not listed
Asteropeia micraster Hallier f.	Asteropeiaceae	EN (A3cd)	Not listed
Leptolaena pauciflora Baker	Sarcolaenaceae	EN (A3cd)	Not listed
Millettia taolanaroensis Du Puy & Labat	Fabaceae	EN (B1+2abc)	Not listed
Sarcolaena delphinensis Cavaco	Sarcolaenaceae	EN (B1ab(ii,iii)+2ab(ii,iii))	Not listed
Ravenea sambiranensis Jum. & H. Perrier	Arecaceae	VU (A1c)	Not listed
Phylloxylon xylophylloides (Baker) Du Puy et al.	Fabaceae	VU (A2cd)	Not listed
Euphorbia lophogona Lam.	Euphorbiaceae	VU (B1ab(iii,v))	2
Dypsis scottiana (Becc.) Beentje & J. Dransf.	Arecaceae	VU (D1)	Not listed
Nepenthes madagascariensis Poir.	Nepenthaceae	VU (D2)	Not listed

DISCUSSION

Re-evaluation of the original 1991 list of priority species presumed to be restricted to the QMM mine site, produced as part of the initial environmental impact assessment, has led to significant modifications, including changes from Priority 1 to Priority 2 status for seven taxa, the removal of 14 taxa from the list, and the addition of 10 taxa newly found to occur at Mandena, all but one of which are classified as Priority 2 taxa (for example Table 1). These changes are the result of two decades of intensive fieldwork, specimen identification and taxonomic analysis, all of which have continued since completion of the revised environmental and social impact assessment in 2001, reflecting a sustained interest on the part of QMM staff and the international botanical community in both the flora of the littoral forests in the Tolagnaro area and the long-term protection of local, range-restricted species.

Expanded inventory work, both within the Tolagnaro area and elsewhere in Madagascar – especially in association with community-based conservation projects in other littoral forest areas such as Mahabo (the nearest sizeable stand to the north of Tolagnaro) and at nearby sites with extensive intact low elevation forest such as Tsitongambarika in the Vohimena range – will no doubt generate valuable information necessitating improvements to the list. Further changes will also result from future taxonomic research as new species are described and the circumscriptions of previously recognized taxa are clarified.

The original flora study conducted for the 1991 QMM environmental impact assessment focused only on identifying species endemic to the mine exploration zone as a whole, without distinguishing between the Sainte Luce, Mandena and Petriky sites. Subsequent analyses in which each site was considered separately have resulted in important refinements to the initial list, indicating that a total of 15 currently recognized priority species are known to occur at Mandena, 12 of which have been found within one or more of the Mandena forest parcels that will be less directly impacted by the mining project [i.e. the Mandena conservation zone (M15/M16) and M7], where their populations are now being monitored closely. Of the three remaining taxa, one occurs at the Sainte Luce conservation zone (a new species of *Pyrostria*) and another at the Petriky conservation zone (*Croton trichotomus* var. *pulchellus*), where monitoring activities are also being conducted, expanding the scope for implementing effective conservation measures, including both *in-situ* and *ex-situ* approaches and the incorporation of these taxa in restoration activities. Just a single apparent Mandena endemic, a new species of *Canthium*, has not yet been located within the Mandena conservation zone or parcel M7, although it has been cultivated at the QMM nursery at Mandena since 2004 and is currently being monitored carefully to gather detailed information on its reproductive biology, including pollination, fruit and seed development, germination, and other key aspects for developing effective *in-situ* and *ex-situ* conservation measures.

Comparison of the priority taxa from Mandena listed in Table 1 with the 15 species from the site that are classified as threatened in the 2008 IUCN Red List shows limited overlap (for example Table 2). While most of the taxa on the Red List must be regarded as of conservation importance, they include only three Priority 2 taxa from Mandena (two that are currently recognized as Critically Endangered and one as Vulnerable). None of the 12 remaining taxa have been assessed using the Red List criteria, a fact that underscores the urgent need to expand efforts to evaluate the entire Malagasy flora, and in particular the island's thousands of locally endemic taxa. The discrepancy between the two lists also helps to illustrate the fact that the current Red List status of some widespread species, such as *Intsia bijuga* and *Leptolaena pauciflora*, both of which occur at Mandena, may not adequately reflect the available information on their distribution and the threats they face. This situation is now being rectified by the IUCN Madagascar Plant Specialist Group, which, in addition assessing

an initial set of ca. 3,000 Malagasy species, is also carefully reviewing and updating earlier assessments.

It will continue to be important to update the list of priority species at Sainte Luce, Mandena and Petriky on a regular basis as new information becomes available, and to adjust and improve activities aimed at ensuring the survival of these taxa. At the same time, it will also be necessary to continue monitoring populations of these plants and to compile information for conservation and restoration efforts, including data on population structure and density, regeneration, and ecological requirements. Further botanical inventory work must concurrently be pursued in other parts of the Tolagnaro region and beyond – especially in areas that have not yet been explored – in an effort to discover new populations of species on the priority list. Finally, intensive studies recently initiated on the priority taxa occurring at Sainte Luce and Petriky, similar to those conducted on plants recorded from Mandena, must be expanded to ensure the long-term survival of the locally endemic taxa restricted to these sites.

ACKNOWLEDGMENTS

We wish to thank QMM / Rio Tinto for logistical, financial and other support that has facilitated our work on the plants of Mandena and the Tolagnaro region, and two anonymous reviewers who provided valuable comments and suggestions on an earlier version of the manuscript. We would like to thank Peter B. Phillipson for help with compiling data on historical collecting efforts at Mandena, and David Rabehevitra for permission to use several of his beautiful photos of plants from Mandena. We are especially grateful to Manon Vincelette for her constant encouragement and support over the last decade.

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Radio broadcasting for sustainable development in southern Madagascar

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ABSTRACT

The Millennium Development Goals have been written into the Madagascar Road Map (2007-2012) in order to improve the Malagasy social, economic and environmental situation. The Andrew Lees Trust Radio Broadcasting Project in southern Madagascar has been set up to alleviate poverty and, through a recent DFID (Department for International Development) funded evaluation study, has demonstrated its contribution and work towards the United Nations targets set for 2015. This article draws on the DFID study, "The Contribution of Radio to Millennium Development Goals in Southern Madagascar", to illustrate the project's success in approaching the main goals of poverty alleviation and education. Radio is a cost effective, non-formal learning medium, which can reach across vast geographic distances to communities in the most remote and isolated regions, and can deliver vital development information to all members of the community irrespective of age, gender, or beliefs. This article reinforces the assertion that radio can act as a vital tool in reaching Millennium Development Goals in Madagascar and beyond.

RÉSUMÉ

Les Objectifs de Développement du Millénium ont été inscrits sur la Feuille de Route de Madagascar afin d'améliorer la situation sociale, économique et environnementale à Madagascar. Le projet d'émission radiophonique de l'ONG Andrew Lees Trust a été élaboré pour lutter contre la pauvreté et s'est avéré capable d'apporter des éléments décisifs pour atteindre les objectifs fixés par les Nations Unies pour 2015 selon une étude récente du Département pour le Développement International (DFID). Cet article s'inspire des études du DFID "The Contribution of Radio to Millennium Development Goals in Southern Madagascar" pour illustrer en partie la réussite du projet quant à la réalisation des principaux objectifs que sont l'éducation et la diminution de la pauvreté. La radio est un moyen de communication peu onéreux, qui ne nécessite aucune formation particulière mais qui a la capacité de couvrir de vastes zones géographiques pour atteindre les communautés les plus isolées et les plus reculées afin qu'elles aient accès, quel que soit leur age, sexe, et croyance, à des informations essentielles portant sur le développement. Cet article confirme l'importance vitale de la radio pour atteindre les Objectifs de Développement du Millénium à Madagascar.

KEYWORDS: Millennium Development Goals, Sustainable Development, Radio Broadcast, Madagascar

INTRODUCTION AND APPROACH

MILLENNIUM DEVELOPMENT GOALS AND ROAD MAP MADAGASCAR

The origin of the sustainable development concept can be traced back to Barbara Ward's 1972 book "Only One Earth", although she did not use the term 'sustainable development', and to the World Conservation Strategy, which was formulated by the International Union for Conservation Nature IUCN, the World Wildlife Fund for Nature WWF and the United Nation's Environmental Programme UNEP (IUCN 1980). This strategy emphasized the need to ensure the sustainable management of species and ecosystems. It can be looked at as the roots of the concept of sustainable development. It was in the Brundtland Commission's Report (1987) "Our Common Future", where this concept of sustainable development has been formulated as a global vision: "Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs." That vision enabled manifold interpretations and two dominant movements emerged: *environmentalism* (promoting the protection of nature from economic ravages) and *sustainability* (promoting economic reformation in order to mitigate environmental crises) (Bailey 1990). A convergence between the two movements aimed at promoting environmental, social and economic dimensions of development (Opio-Odongo 2003). The Millennium Development Goals originated from a series of United Nations conferences where different resolutions and agreements were made in the 1990s. In 1996, OECD / DAC (the Organization for Economic Co-operation and Development) proposed the International Development Goals (IDGs), a set of seven quantitative goals as a possible road map to sustainable development (IMF / OECD / UN / World Bank Group 2000, United Nations 2000). In the year 2000, representatives of 180 countries transformed the seven IDGs into the eight Millennium Development Goals (MDGs) during the landmark Millennium Summit.

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Essentially, the MDGs with its 18 targets (see Table 1) and 48 indicators became the road map to the sustainable development goals (United Nations 2007). Since poverty is a complex issue, the first seven goals (Table 1) are mutually reinforcing and should possibly abate poverty in all its facets, whereas MDG8 represents the framework which should ensure the achievement of the other MDGs by 2015.

In Madagascar, as well as in many other sub-Saharan countries, the prospects of susceptibility to negative shocks due to catastrophic weather and other natural events (e.g. cyclones, droughts), coupled with the fact of fertility rates and population growth outpacing many other regions in the world, will be especially challenging for the achievement of the Millennium Development Goals by 2015 (Sahn and Stifel 2003). The new Malagasy government in charge since 2002 has therefore established in 2006 an ambitious development strategy termed Madagascar Action Plan (United Nations 2006). It intends to accelerate and coordinate this development process in order to help Madagascar achieve its MDGs as well as overall economic development. The eight commitments of the Madagascar Action Plan have diverse foci like "cherishing the environment", "rural development and a green revolution", and "health, family planning and HIV / AIDS." Key aspects of this plan are the environmental conservation and human health interventions (United Nations 2006).

CONCEPT, RESOURCES AND METHODS The Andrew Lees Trust (ALT), a UK-based NGO, has been implementing an educational radio broadcast project known in French as 'Projet Radio' (PR) in Madagascar since 1999, following a six months feasibility study. The project aims to empower isolated rural populations across the southern provinces of Toliara and Fianarantsoa (Figure 1) to improve their food security and alleviate the effects of poverty through education delivered by radio. PR's work is founded on the collaboration and networking of three groups: local radio stations (Figure 1), village listening groups and NGOs / local service-providers. Listening Groups consist of 10 to 15 people within a community (Vadgama 2006).

Over three quarters of the rural population are illiterate (World Bank 1996), and villagers have few means to learn how to improve their situation and reduce their economic and social vulnerability. However, aural learning traditions in Madagascar, especially in the southern part, give people a great capacity to listen to radio and remember details of key messages (Bouwer 2007). Radio programmes cover a range of topics including cattle rearing, animal husbandry, food security, farming, natural resource management, environment, healthcare, HIV / AIDS awareness, family welfare, education and culture. On average, 30-40 radio programmes are developed every month by ALT and collaborators. 2,242 programmes have been broadcast between 1999 and 2008 (see Table 2 for an overview).

Members of a community forming together as a Local Listening Group will share one radio, which has been distributed by ALT and its partners. These groups sign a contract of collaboration with the PR, which in turn allows the Listening Groups to follow programmes broadcast by ALT and partners. PR has developed a participative approach, which is designed to respond to villagers' information needs and produce solution-oriented educational broadcasts in local languages. The programmes are currently distributed to 40 local FM radio stations affiliated to the PR across the provinces of Toliara and Fianarantsoa (Figure 1). The stations broadcast the programmes in exchange for radio equipment to increase their signal coverage and quality of programming. These educational programmes reach more than 700,000 people across the two provinces, as a minimum of 10 % of the population also own radios. Villagers receive the broadcasts via Freeplay clockwork and solar-powered radios, which the project places with the village responsible that is

TABLE 1. Millennium Development Goals (MDGs) and respective targets (T); the third column represents the fields of radio programmes developed by ALT and partners, and in brackets are the numbers of broadcasted programmes (derived from Harford 2007).

Millenium Development Goal (MDG)	Target (T)	ALT Radio Topics
Eradicate extreme poverty and hunger, by halve between 1990 and 2015 (MDG1)	the number of people whose daily income is below one US$ (T1); the number of people who suffer from hunger (T2)	Rural Development (147), Agriculture (304), Food Security (3), Livestock (86), Fishing (11)
Achieve universal primary education by 2015 (MDG2)	in that all the children, girls and boys alike, shall be able to attend and complete a course of primary school level education (T3)	Education (62)
Promote gender equality and empower women by 2015 (MDG3)	in eliminating genderinequality at all levels of education (T4)	Culture (22), Rights (3)
Reduce child mortality between 1990 and 2015 (MDG4)	in reducing the under five year old child mortality rate by 66 % (T5)	Health (539)
Improve maternal health between 1990 and 2015 (MDG5)	in reducing the maternal mortality rate by 66% (T6)	
Combat HIV/AIDS, malaria and other diseases by 2015 (MDG6)	in halting and reverse the trend of spread of HIV/AIDS (T7); in halting and reverse the incidences of malaria and other major diseases (T8)	
Ensure environmental sustainability by 2015 (MDG 7)	in integrating the principles of sustainable development into country policies and programs (T9); in halving the proportion of people without regular access to safe drinking water as well as basic sanitation T10); in achieving by 2020 a significant improvment in the lives of at least 100 million slum dwellers globally (T11)	Environment (354)

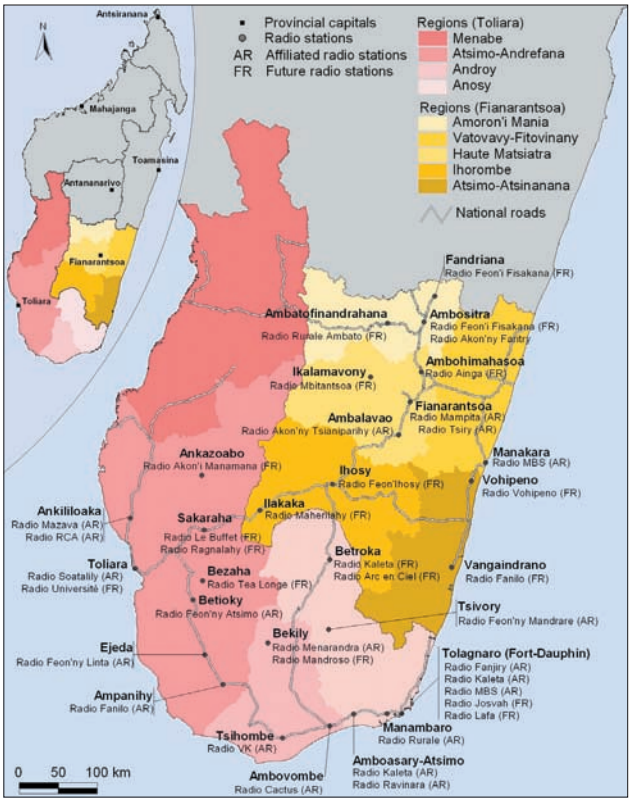

FIGURE 1. ALT's affiliated (AR) and future (FR) radio stations in the 'Projet Radio' in the regions of Toliara and Fianarantsoa in south Madagascar.

elected to take care of the radio. The radios are both environmentally and economically appropriate, requiring no batteries or other external energy source. PR now involves more than 3,371 Listening Groups, who agree to collaborate in the project by participating in programme research, production and monitoring to allow for an 'adaptive research approach' (see Figure 2). Research has shown that members of the community who are not directly involved with a Listening Group still benefit from the radio broadcasts due to information-sharing traditions within the village (Smith 2001, Metcalf 2006).

In order to assure a holistic approach and high quality expertise, ALT has engaged in project cooperation with more than 47 local NGOs and service providers associated as Partners for Communication and Information Development (PCID) (for more details on PCID see Harford 2007). All affiliated radio stations are local community or commercial FM stations. Radio programmes are tailored in local dialects, using formats that are relevant to villagers. The participative production cycle process gets as close as possible to the needs of the audience, but without villagers actually making the programmes themselves. However, this year, following recommendations of the DFID (Department for International Development) evaluation (Metcalf et al. 2007), the project has begun training villagers to record programme content themselves.

OBJECTIVES AND PLAN The objectives of this article are two fold: (i) to demonstrate the potential of radio broadcasting as a high efficiency/low cost means to meet IDGs / MDGs in Madagascar, but also beyond Malagasy border, by presenting ALT's efforts in southern Madagascar published so far in the form of several project and evaluation reports on the ALT website (http://www.andrewleestrust.org/radio.htm), most specifically the DFID evaluation study which highlights project results in the

TABLE 2. Broadcasted programmes in Ejeda between August 2004 and December 2005. In total, 463 radio broadcasting programmes were produced and aired by ALT and its PCID-partners, with all of these programmes being broadcasted at least once during the month they are received by the radio stations (numbers from Metcalf 2006).

Topics	# of Broadcasted Programs
HIV/AIDS	55
Breastfeeding	10
Family Planning	10
General Health	10
Vaccinations (not Polio)	8
Sexually Transmitted Diseases	7
Hygiene	6
Polio	5
Malaria	5
Prenatal Consultation	4
Drinking Water	3
Tuberculosis	2
Cholera	1
Planting Vegetables for Healthy Diet	1
Pregnant Women's Health	1

context of the Millennium Development Goals; and (ii) to draw conclusions to which extent this approach can be used and extrapolated into other contexts, in answering the questions: How can radio broadcasting help to achieve the Millennium Development Goals? And how and where more emphasis could be given to the educational radio programmes? The key items here seem to be based on a secure network of cooperation at local, regional and national levels, on sufficient radio infrastructure, the functioning of adaptive reporting in radio broadcasting, and on the cost effectiveness of the PR's goals, especially in terms of education, environment and public health.

The preceding subsection outlined the concept, resources and methods of the approach adopted by ALT. In the following section are presented a selection of important results and impacts of the Radio Broadcasting Project pertaining to the MDGs, and the last section summarizes this article and gives some recommendations for potential further application of the PR's ideas.

RESULTS AND IMPACTS OF THE RADIO BROADCASTING PROJECT

According to the chronology 'IDG1996/ALT-PR1999/MDG2000/UN-Road-Map2007', ALT set up this project before the Millennium Development Goals were laid down – ALT has never claimed that it purposefully set out to meet MDGs – but ALT did set out to empower people to alleviate the effects of poverty and extended its activity across all development sectors – hence ALT then hit the MDGs. Although the project has carried out various monitoring activities over the nine years of its operation, in 2006 ALT secured funding from DFID (Department for International Development) to carry out an extensive evaluation of the project impacts. This was aimed to contribute to wider studies within the ICD (Information and Communication for Development) department of DFID to assess the importance of media for development. The consultancy group Media Support Solutions was commissioned by ALT to design and direct the evaluation

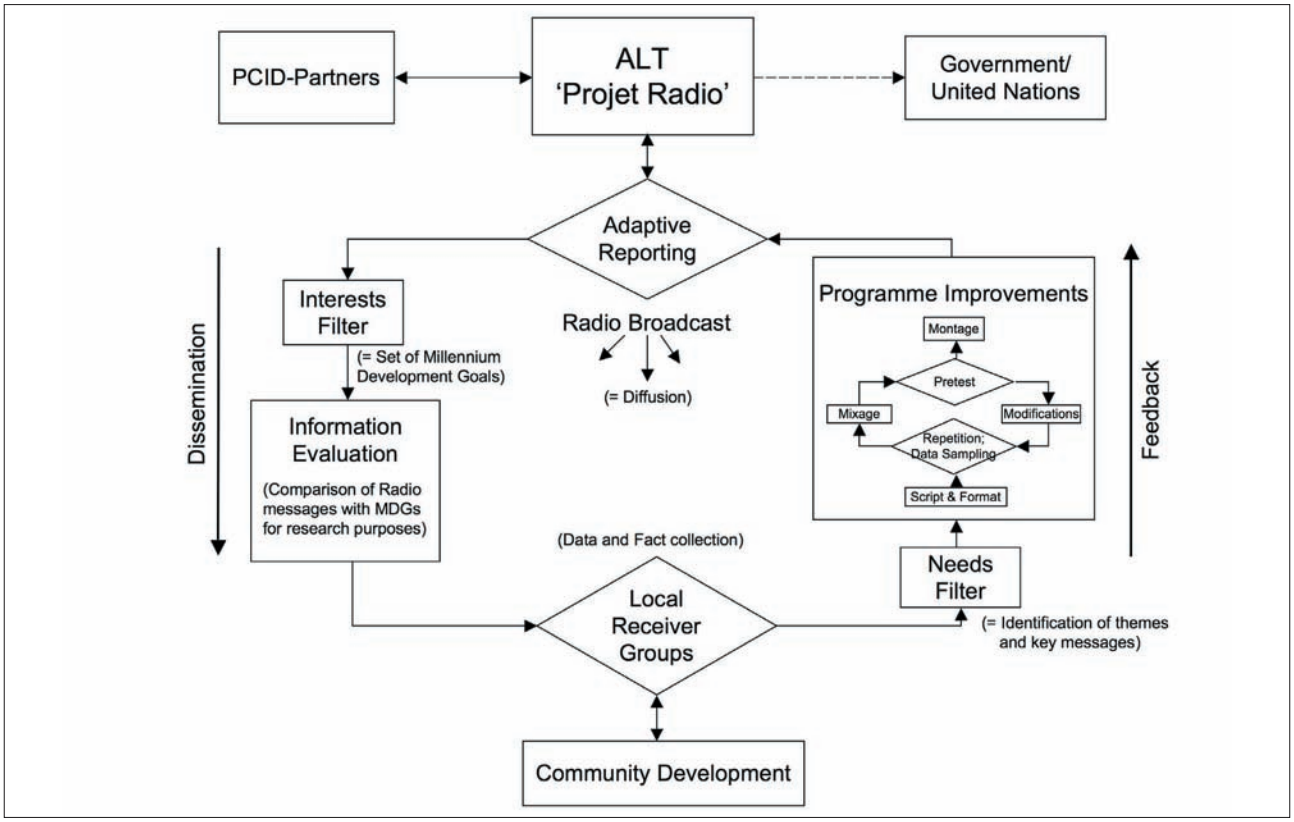

FIGURE 2. Concept and flow of sustainable development values and activities (e.g. MDGs), realized by Radio Broadcast and Local Listener and Receiver Groups in the ALT 'Projet Radio'. MDGs: Millennium Development Goals; PCID: Partners for Communication and Information Development.

was commissioned by ALT to design and direct the evaluation process and a research coordinator (Leo Metcalf) was appointed to oversee the study activity in the field over fifteen months. Given the project's multifaceted approach, an evaluation matrix was designed to measure specific project results in the context of Millennium Development Goals.

Eleven research studies were carried out across the project area in southern Madagascar (Figure 1) between August 2005 and December 2006, which fed into a final analysis published by Metcalf et al. in 2007. The respective methodologies applied in the field research are detailed in separate reports referenced in the subsections below. In summary, qualitative methods like structured and semi-structured interviews have been used to evaluate a range of project activities and topics (e.g. Wengraf 2001). Tools like questionnaire-based interviewing of large random samples of up to 273 people, to small focus groups (e.g. Listening Groups), participative mapping, and interviews with key informants were applied.

ERADICATE EXTREME POVERTY AND HUNGER (MDG1)

The World Bank in its Madagascar Poverty Assessment (1996) writes: "The most striking features of poverty in Madagascar as identified by the poor are isolation and powerlessness. The poor lack the means of communications with all but their own immediate community". In Madagascar, for many years the media were heavily restricted, but over the last ten years the press has been increasingly liberalized and, in 2006, the Ministry of Communications registered 244 radio stations throughout Madagascar. Radio provides a forum of communication, interactive exchange, amongst but especially between rural communities (Van Crowder et al. 1998, Ilboudo 2000 and 2002, Rakotoson 2002). Nevertheless, poverty and illiteracy still severely limit access to information, because many cannot afford to buy radios or batteries, and electricity is often not available outside the urban areas. Widespread illiteracy also severely limits the spread of the written press.

Madagascar is a Least Developed Country, with a population of approx. 20 million people (CIA Worldfactbook 2008). The HDI (human development index) is a composite measure of three dimensions of human development, i.e. long and healthy life, education, and standard of living. The HDI for Madagascar is 0.533, which ranks Madagascar as 143rd out of 177 countries. 85 % of the Malagasy population lives on less than $2 US a day (Gaffikin et al. 2007), and the situation is particularly precarious in the south where frequent drought causes chronic food insecurity (UNICEF 2007, IRIN 2007).

ALT / PR and its partners have so far produced over 400 radio programmes specifically on the subjects of hunger and poverty. The topics of the radio programmes range from controlling diseases in livestock, to improved techniques for rice-planting, to advice on laws and rights, loans, fishing and bee-keeping. All these actions are accounting to the targets T1 and T2 of MDG1 (see Table 1).

In order to evaluate the importance of radio in terms of sources for news and knowledge, ALT has performed a comparison between five villages (totalling 134 villagers) with non-existent or very low access to radio, and six villages with good access to radio signals (with a total sampling size of 268 randomly selected villagers) (Metcalf 2006, Metcalf et al. 2007). Both sets of villages were otherwise identical in socio-economic terms. Generally, this

comparison revealed that women were particularly influenced by radio, since men have access to other information sources, such as word of mouth, due to their greater mobility. In the question "Where do you get your information about agricultural matters?" radio was mentioned most often in villages that had regular access to radio (Listening Groups) (with 50 % mentioning "radio", and 39 % mentioning "word of mouth"). Whereas in villages that had no radio access "important men or notables" were the main sources of news (with 53 %), and with 40°% of the respondents opting for "word of mouth" (Metcalf et al. 2007).

In terms of whether listeners had been able to implement ideas or advice they received via the project's radio programmes, 80 members (men and women) of eight radio Listening Groups who had been listeners since 2002 were interviewed. Three out of eight members of these Listening Groups had built windbreaks to protect cotton fields; three groups had used insecticides to protect their crops; four had tried to follow radio advice on grafting manioc, and three had planted sorghum. Thanks to the radio information, the majority of Listening Group interviewees claimed to use now "modern agricultural techniques". Furthermore, four out of eight groups said they now vaccinate their cows; and three groups revealed that they consult veterinary help if a cow is sick (Metcalf et al. 2007). Interestingly, three out of these eight listening groups have shown initiative and founded an association, which is eligible to apply for local development funding.

These results show that radio is a source of help in terms of bringing new ideas and presenting alternatives to remote areas in order to improve agricultural techniques and approaches to alleviate poverty and hunger (T2), and to increase possibilities of income (T1). This is especially valuable in regions where outreach and exchange is scarce and where illiteracy amongst the population is quite high (FAO 2007).

ACHIEVE UNIVERSAL PRIMARY EDUCATION (MDG2)

Rural life often causes poverty and illiteracy. Hence, improvement in education can create opportunities and strengthen skills, which in turn can strengthen and enhance peoples' livelihoods, productivity and income (Girard 2003, Shibeshi 2006). According to UNESCO (2005a) about 30 % of the population is literate and only 37 % finish primary school. Poor primary school children are more likely to be out of school than richer ones (UNESCO 2005b).

As literacy is an integral part of education (see T3, Table 1), ALT helped to promote local literacy classes in the Androy, an area with a poor reputation for school attendance and attaching little importance to formal education since the principal traditional livelihood is cattle rearing. In this region cattle are not simply a capital asset but are also sacred. Cattle are slaughtered at death to assure a better afterlife and are therefore highly prized (for more details on the Androy culture see Metcalf et al. 2007).

The literacy project began with a simple radio announcement requesting local communities to submit a list of those adults interested in attending literacy classes to the co-coordinating NGO, 'Tahantanee' in Tsihombe. ALT then developed a full radio campaign to broadcast the advantages of the literacy programme. Key messages included (i) the literacy programme is free, there are no costs involved in learning – the students can use charcoal and old sheet metal or the blade of a spade to write with (ii) the programme offers the prospect, through literacy, of freedom from the embarrassments of illiteracy such as fingerprinting and the risk of being easily defrauded.

According to the tracking records of the request numbers for attending this educational programme, the radio broadcasting has attracted in the period between 1 April 2005 and 15 December 2005 up to 25,000 students (with an age range between 20 and 80 years) distributed over 800 training centres (Lellelid 2006). This is a very large number of attendees, which would have never been possible without radio, and also shows the scale of demand from the population for literacy and education. In questionnaire surveys carried out by local researchers, different motivations for attending this listening literacy classes were identified: for 31 % (out of a total sample size of 161 adults) it was the ability "to read", and for 15 % each "to write", or "not to be cheated by others"; for 11 % each it was the ability to "sign by name", or to "calculate", or to "send letters"; 6 % wanted to "avoid the fingerprint" (often used as a form of signature) (Lellelid 2006). These results nicely show that it is important to the villagers to be as independent as possible, and they appreciate having been offered an opportunity through the radio to participate in the literacy programme, as reflected in the relatively high number of students who enrolled. Another study showed that most of the adults attending these literacy classes came by foot to the learning centres (269 out of 274 interviewed), and the others did so by bike or ox-cart. Obviously, the farther away such a reading centre was located (0.25-20 km), the lower was the motivation to attend the programme. Interestingly though, the closer such a centre was the more women did attend it (e.g. within a distance of 0.25 km, 49 % of all interviewed women attended, but only 26 % of all interviewed men) (Lellelid 2006). This highlights the particular importance of radio enabling women, who are more housebound than men, to attend education classes. This can particularly help women who carry the major responsibility of managing a family.

PROMOTE GENDER EQUALITY AND EMPOWER WOMEN

(MDG3) In southern Madagascar, women have traditionally played a secondary role in decision-making. Their status is subordinate to men, and their inferior status has many negative consequences for their education, health, nutrition and life-prospects. Poverty has forced men to migrate away to work for long periods, leaving 25 % of households headed by women (Metcalf et al. 2007). ALT has actively promoted women's role in development and ensured that women were given priority in leading Listening Groups and being responsible for managing access to the radios within the village setting. Women represent a stable presence in the village and are less subject to hierarchical issues in the traditional village structure. Consequently, they guarantee better access to the radio for community members. To date, 68 % of all the heads of Listening Groups in the PR are held by women (Metcalf et al. 2007).

ALT's research found that women's inferior access to information compared to men could be greatly improved by the use of radio broadcasts, which would work towards the achievement of T4 of MDG3 (Table 1). For example, one research study was conducted in Ejeda, Mahafaly region (Figure 1), where ALT and UNICEF had helped to install a new FM radio station in a local hospital in order to focus specifically on mother and child health issues which are particularly problematic in this region due to cultural practices. (e.g. the use of '*Tisane*' for new born, but see MDG5 for more details). Sales of radios to local people escalated after the installation of the radio station and a number of Listening Groups were set up by ALT to work in collaboration with hospital health radio journalists.

70 women exiting the hospital were interviewed: "How do you receive information on health?" The answers were: "radio" (49 answers), "friend / neighbour" (36 answers), "local authority" (27), "hospital" (23), "word of mouth" (13), or "market" (2); "Which sources give you the most information?" The women gave the following answers: "radio" (33 answers), "friend / neighbor" (20), "local authority" (11), "hospital" (5), "*ombiasy*" (Malagasy for traditional healer) (1). "Why did you consider the radio as source for information?" Here, four different reasons were mentioned: "easily accessible" (25 answers), "reliable" (11), "easy to understand" (since it speaks the local dialect) (8), "gives practical advice" (1). For all the questions multiple answers were possible (Metcalf 2006). For women who are at home, or at least spend most of the time in their villages, radio seems to be a quick and reliable way of access to information, which is important for acquiring more knowledge and understanding, which in turn are fundamental for decision-making and family planning. This becomes especially imminent if decisions have to be made in terms of health where time is an important and often restricting factor.

REDUCE CHILD MORTALITY (MDG 4) AND IMPROVE MATERNAL HEALTH (MDG 5) Health indicators for Madagascar are generally comparable to averages for sub-Saharan Africa; however, Madagascar ranks substantially below this average on child malnutrition (World Bank 2001). Access to health care and services is still a major challenge in Madagascar for the poor. Economic, political, administrative, geographic and socio-cultural factors all influence peoples' behaviour in seeking access to health services. Unaffordable health care costs represent an important barrier for poor people to access health services; these can include, for example, transportation costs to overcome distances, or lost working time (Glick and Razamanantsoa 2005). In Madagascar the probability of a child dying during its first five years of life is 115 ‰ and the mortality rate for infants < 1 year is 72 ‰. In 2006, there were an estimated 82,000 (< 5 years) child deaths mainly due to malaria, diarrhoea or respiratory problems (UNICEF 2006). In the south, health services are particularly scarce with only 49 % of women able to access and use skilled antenatal care (Metcalf et al. 2007).

ALT and partners have produced a variety of radio programmes on themes like childhood diseases and hygiene (in order to achieve MDG4/T5), as well as on the advantages of prenatal consultations (to achieve MDG5/T6, Table 1), of vaccination, exclusive breast-feeding and family planning (Table 2). In a study on "How to avoid pregnancy?" the ALT team has interviewed 134 women. The ones from villages with good radio reception (i.e. they were able to follow the aired programmes of the PR) were more knowledgeable about all types of family planning methods than those from villages with low radio listening (i.e. they were not able to follow the PR broadcasting). For example, 46 % of the former knew about contraceptive pills compared to only 18 % in the latter (Metcalf et al. 2007). Knowledge and understanding are the basic steps towards a change of attitude.

In an evaluation conducted by Johansson (2005) for UNICEF / ALT, 56 persons (35 men, 21 women) from Listening Groups, and 53 persons (19 men, 34 women) from non-Listening Groups were interviewed on five health topics: diarrhoea, infant feeding, polio vaccination, pregnancy and malaria.

For the question "What would you do if your child got diarrhoea?" 71 % of Listening Groups (LGs) answered "give the baby water often" in contrast to 32 % of the non-LGs; and 95 % of the LGs answered "bring the child to the hospital", in contrast to 23 % of the non-LGs. 32 % of these would also "give the baby a tisane" (a traditional practice of administering a plant-infusion / tea which is given in large quantities to new born and which can result in severe sickness or death) whereas only 5 % of the LGs would do so too.

For the question "How would you feed your baby?" 79 % of the LGs gave the answer "breastfeeding exclusively" in contrast to 23% of the non-LGs, whereas 49 % of the latter would "give the baby a tisane", comparing to only 9 % of the LGs.

For the question "Why should you let your children get vaccinated?" 71 % of the LGs answered "to protect it against poliomyelitis"; in contrast, only 8 % of the non-LGs did so too.

For the question "What do you do if you think you are pregnant?" 75 % of the LGs answered "vaccination", in contrast to 58 % of the non-LGs; 54 % of the LGs would "treat illness", in contrast to 13 % of non-LG. 17 % of the latter would "take tisanes", whereas only 2 % of the LGs would do the tisane treatment.

For the question "What can you do to prevent malaria?" 86 % of LGs, and 77 % of non-LGs answered "use a mosquito net"; 41 % LGs and 6 % non-LGs answered "take Nivaquin every week"; 0 % LGs, and 4 % non-LGs answered "I don't know".

The research found that 89 % of women from villages with radio (= with LGs) had vaccinated their children compared to only 75 % of those from villages with low levels of radio listening (= no LGs). Significantly more women from 'radio villages' (68 %) knew that a child needs a total of five vaccinations, compared to women in 'non-radio villages' (42 %). All villages had equal access to vaccination services, and were visited equally by health workers publicizing vaccination.

These results reflect that people are listening to radio and can gain knowledge and understanding in terms of health issues. However, this does not mean that people will then immediately change their behaviour. Encouragingly, Metcalf et al. (2007) found that most of the advice broadcast during radio programmes was being practiced by the Listening Groups. ALT found that, out of 100 Listening Groups (LGs), the health ideas from radio programmes were reportedly being put into practice by a majority of participants in the PR as follows: the "use of mosquito nets" is mentioned most (46 LGs), followed by "use of condoms" (32 LGs), take-up of family planning measures such as "injections and pills" (31 LGs) and "prenatal and neonatal care" (25 LGs) (Metcalf et al. 2007). A further study should aim to measure whether (and if so, to what extent) the disease incidences of children and mothers have been reduced thanks to radio broadcasting efforts in order to clearly support the indicators listed in Table 1.

REDUCE HIV/AIDS AND OTHER DISEASES (MDG 6) According to UNAIDS, an HIV rate of over 1 % represents a 'generalised epidemic'. Therefore, a national average HIV rate among pregnant women in antenatal clinics of 1.1 % recorded in a survey performed in 2003 (UNAIDS / WHO 2004) did activate a re-orientation of the national strategy. This forced the responsible authorities to reach directly every individual in the country with essential information on HIV instead of focusing efforts on specific populations (with the exception of people living with HIV). However, rural areas are often ignored in HIV surveillance, since the population has often limited access to health care, education, and media (print, radio, television) (Leutscher et al. 2003). Although HIV infection is usually less

prevalent in rural areas (e.g. less tourists, and therefore less exchange with outsiders), rural prevalence continues to rise (Munguti et al. 1997).

ALT launched ALT 'Projet Radio SIDA' in January 2004 in order to offer radio programmes in local languages / dialects on themes of HIV / AIDS. A central aim of this project is to enhance the understanding of this disease amongst vulnerable groups of people, which works towards the MDG6, target T7 (see Table 1). Researchers analyzed the impact of a specially commissioned series of radio programmes on HIV / AIDS broadcast between 2004 (Phase I) and 2005 (Phase II), covering a variety of HIV / AIDS awareness themes (Metcalf 2005).

A questionnaire-based enquiry was carried out over two months by local researchers, targeting 270 randomly selected individual interviewees with the respondents representing a cross-section of rural and urban dwellers, with roughly equal numbers of people who claimed to be members of Listening Groups (LGs) as there were non-LG members. Respondents were asked to list their personal sources of information about HIV / AIDS in order of importance: "Did you hear about HIV / AIDS; if so, what type of media; what are your other sources?" (Metcalf 2005). On average 89 % opted for "radio" (with 96 % from urban and 82 % from rural respondents), 53 % "programme leader / NGO", 39 % "posters", and 30.5 % "television" (with 59 % urban, and 2 % rural respondents). Radio is clearly the most pervasive source for both rural and urban areas, whether they are members of an LG or not. Interestingly, during Phase I of project ALT PR / SIDA (i.e. before 2004) radio was already the most important source of information, but at a much lower percentage (51.5 % versus the 89 % of Phase II); in Tsihombe (Figure 1) it was 26 % in Phase I versus 100 % of the interviewed in Phase II.

In the same Phase II interviews of 2005, questions on beliefs and knowledge on HIV / AIDS were posed (Metcalf 2005): "What can you tell me about HIV / AIDS?" 85 % of the respondent quoted "AIDS is a disease", of which 60 % declared that "AIDS is a sexual disease", 52 % of all the interviewee answered that "AIDS is incurable", and 58 % "AIDS can lead to death". Although in 2004 in Phase I 20 % answered to the same question "AIDS does not exist", still 10 % of the Phase II interviews still opted for the same. It is one of ALT's most challenging goals to reduce this belief to 0 %.

"Could you tell me the ways in which HIV / AIDS is transmitted?" 96 % "sexual relations" (of which 58 % precised that "unprotected sexual relations" are the cause); 78 % "blood"; and 38 % "mother to child"; 15 % "mosquitoes". Interestingly, 20 % of the urban interviewee opted for this belief, whereas only 10 % did so from the rural area. This could be due to the faster spread of rumours in urban areas, or it could be because rural areas are still more traditional and do not talk openly about beliefs. These results show that the programmes produced by ALT and partners on HIV / AIDS can change the knowledge and understanding amongst urban and rural population, and also reverse the general trend of disseparation between rural and urban areas (Sahn and Stifel 2002). Three quarters of respondents were able to identify that ALT 'Projet Radio' had produced the programmes on HIV / AIDS, only 18 % of respondents could not remember who produced these programmes (Metcalf et al. 2007). The ALT programmes were so memorable that in some cases members of Listening Groups could even repeat entire dialogues from these radio series, or were able to recite whole poems previously broadcast. Radio is certainly a medium that is particularly well suited to overcoming the lack of general information sources in rural areas, and if aired in the local language, a high number of people can receive and understand the messages. Further, the greater the frequency of the programmes being aired, the higher the chances that people will remember the messages. This is certainly a prerequisite for meeting MDG6/T7 (Table 1).

ENVIRONMENTAL DEGRADATION (MDG 7) Known for its highly biological diversity (Myers et al. 2000), Madagascar has attracted the interest of many donors and international agencies. For example, Madagascar was one of the first African countries benefiting from the NEAP – the National Environmental Action Plan (Mercier 2006). Nevertheless, the high degree of poverty and the strong demand for wood, mainly in form of charcoal, are putting heavy pressures on the remaining forests, i.e. an average Malagasy family in southern Madagascar uses about 1,200 kg of charcoal *per annum* (Vetter 2006).

The ALT radio project, in collaboration with PCID partners, has produced over 354 radio programmes on the environment. The broadcasts cover a broad range of topics including the promotion of fuel-efficient stoves and tree-planting as well as the consequences of *tavy* slash-and-burn agriculture and the protection of threatened species like the Radiated tortoise, *Astrochelys radiata*.

ALT introduced a fuel efficiency project in 1999, which trained rural women to build the *Toko-Mitsitsy*, a fuel-efficient wood stove, which can reduce wood consumption by up to 75 %. Additionally, ALT has also been engaged in tree planting and established a tree nursery in Tsihombe in 2003. The aim is to grow a variety of seedlings that can offer local food, fuel, and soil stabilization, including mango (*Mangifera* spp. Anacardiaceae), papaya (*Carica papaya* Caricaceae), moringa (*Moringa oleifera* Moringaceae), and filao trees (*Casuarina equisetifolia* Casuarinaceae). Seedlings are sold at affordable prices to individuals or distributed free to local not-for-profit associations (Metcalf et al. 2007).

In 2006 ALT assessed the extent to which radio informed and encouraged people to purchase trees, or local associations to apply for free trees from the tree nursery. Results showed that radio was responsible for 59 % of trees distributed from the nursery whereas 35 % were attributed to face-to-face communications with ALT staff (Metcalf et al. 2007).

ALT's evaluation of the impacts of the *Toko-Mitsitsy* involved a survey of 268 (including 134 women) randomly selected respondents from 11 rural communities in the south of Madagascar (Metcalf et al. 2007). In contrasting the women from 'radio villages' with 'no-radio villages', on average 61 % of the former showed a higher understanding of this cooking tool and were also using a *Toko-Mitsitsy*, whereas only 47 % of the latter did so too. Interestingly though, both the 'radio' and 'no-radio villages' have been visited equally by ALT field agents to promote the new stoves. According to field agents in the villages with radios, the women were more willing and much less reluctant of adopting and applying these new stoves, and this can be put down to radio broadcast information spread. For example, survey-village number three, where the women have been well organised in regular radio Listening Groups since 2002, showed even better results: 81 % of the respondents did know and / or were using a *Toko-Mitsitsy*. Radio, therefore, can promote and ease the establishment of new tools with higher efficiency and contribute to the reduction of wood use, which is working for achieving MDG7, target T9.

CONCLUSIONS

The ALT 'Projet Radio' is affecting the villages and communities in terms of enhancing knowledge and understanding, and in starting to change attitudes on topics such as HIV / AIDS (MDG6), family planning, mother and child health (MDG4/5), environmental (MDG7) or social and administrative issues (MDG8) and gender inequality (MDG3). Education is at the front line of achieving the Millennium Development Goals (Gasperini and Zulberti 2003), and radio is facilitating this for a range of ages, men and women alike. The environment and its relation to sustainable agricultural development and food production present an enormous challenge in terms of proper use and the conservation of environmental resources. These are often degraded by the poorest, which are mostly rural people with no alternative for meeting their daily needs for land on which to grow crops, or fuel wood. Unsustainable use of resources can only be halted if new schemes of incentives and techniques of cultivation are brought to these remote areas. Such solutions, however, will have to be made accessible and acceptable to local people, many of which will need considerable encouragement and training in new skills (Fraser and Villet 1994). That is where the role of communication, i.e. in form of radio, has its main potency. Radio is also having a positive impact on uptake of health services, enrolment in literacy classes (MDG2), construction of environmentally friendly woodstoves, tree-planting, agricultural yields, and awareness of strategies for poverty reduction through income generation and community associations (MDG1).

Generally, radio is a medium that easily can reach remote areas and overcome distances, where other media like printing or television face greater challenges. With radio, even the very poorest members of the community can have access to information, which can help to tackle everyday problems. However, to receive news from radio broadcasting, a village needs to be able to receive such signals. These demand service providers, who ensure the radio coverage of such remote areas. ALT / PR has invested substantially in radio infrastructure in the regions where it works, launching two new stations in areas where there was no FM signal and providing access to educational broadcast for thousands of new listeners. The project has also provided equipment upgrades for over 20 stations to date, with further supports imminent for another 19 stations.

Households need to have a radio device in order to receive these frequencies. Service providers, like radio sets do not come free, but activities like ALT's 'Projet Radio' can gather into a network of collaborations and funnel funding and expertise (e.g. trainers and specialists) into remote regions like the provinces of Toliara and Fianarantsoa. Such projects also help build local capacity, which is the basis of future independence and assures a long-term sustainability of information provision when project funding ends. However, given the community benefits from such projects, continuous effort must be assured in the form of local training to develop high quality programme content which can help enhance the knowledge and understanding of the local audiences and work towards the MDGs.

In order to measure whether indicators and targets are met, the impacts should be evaluated on a regular basis, to identify where to improve and enhance future efforts. The 'adaptive reporting' can help radio projects become even more effective (see Figure 2). Critical to its success is ALT / PR's decision to train NGO outreach workers to make radio programmes promoting their specialized topics, rather than follow the usual course of training radio broadcasters to make programmes on unfamiliar subjects of which they have little understanding. The ability of radio to scale-up and extend the on-the-ground work of local service-providers emerges quite clearly. Since ALT / PR embraces a participatory approach, the communities have opportunities to express their needs, radio broadcasting programmes are tailored in a manner to meet these needs (e.g. 'needs filter'), and communities can feedback on the programmes (see Figure 2 for more details). However, this process can be challenging especially where community demands are high and staff resources limited. It is therefore of utmost importance that such projects and approaches are based on a secured network of cooperation at local, regional and national levels.

ALT / PR is cost effective – education is delivered at a cost of less than a dollar per head per year (for a summary see Metcalf et al. 2007) and has a high local reputation, i.e. communities see a direct benefit of the radio programmes, and are also keen to participate in Listening Groups and monitoring of programmes. These are two important factors showing that this approach of helping to achieve the Millennium Development Goals, i.e. to alleviate poverty, can be fruitful in regions like southern Madagascar, where many communities are isolated and often have been neglected by the international development community.

There is a growing focus on the role of media for sustainable development in Madagascar. ALT has now shared its model and methods with CNLS (National HIV / AIDS Committee of Madagascar), UNICEF and UNDP and the Ministry of Communications who have adopted, or are in the processing of adopting the ALT 'Projet Radio' approach to some of their national communication strategies. Most recently ALT acted as a consultant on a national media communications assessment for UNDP Madagascar and has made recommendations to address communication gaps at local level, implicating much of the model and many lessons learnt in the southern experience of PR. It is hoped that a scaling up and duplication of the PR model will now occur in other parts of the island even where geo-topographic conditions may be yet more challenging.

Radio is a medium with a wide and popular reach. To quote Gro Brundtland: "Sustainable development (i.e. in achieving the MDGs) is a major challenge for the next century. People are central to that task. The only way we can work for a common cause, for common interest, to improve our condition, is really through communication. (…) It has to do with participation, with spreading of knowledge and insight and ability to take care of our future."

ACKNOWLEDGEMENTS

The authors would like to thank the ALT team for providing information and preparing the map. Jean-Sébastien Jacquet is acknowledged for the translation of the abstract. Special thanks to Rafanomezana Mamiarisoa Alice for undertaking local interviews in Toliara and to those members of the PCID and local community who participated in the interviews: Mr. Faralahy and Hantatiana Jacqueline.

Without the funding support from DFID, the extensive research programme undertaken to evaluate the impacts of radio in southern Madagascar would not have been possible. Thanks are therefore due to their ICD department which championed the need for this study and to Media Support Solutions for providing the necessary technical expertise that ensured a thorough and credible research process.

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INTERVIEW MADAGASCAR CONSERVATION & DEVELOPMENT

Two women and one man engaged in the Andrew Lees Trust Radio Broadcasting Project

Mamiarisoa Alice Rafanomezana
Jacqueline Hantatiana
Faralahy

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1) INTERVIEW AVEC MAMIARISOA ALICE RAFANOMEZANA, UNE DES RESPONSABLES DE ALT / PROJET RADIO

Pouvez-vous vous présenter un peu pour commencer ? Qui êtes-vous, quel rôle tenez-vous exactement dans ce partenariat avec le Projet Radio et depuis quand y avez-vous participé ?

Mon nom est RAFANOMEZANA Mamiarisoa Alice. Je suis la Coordinatrice Régionale du Projet Radio de l'ONG Andrew Lees Trust Toliara.

Je me charge plus précisément de la gestion et de l'orientation du Projet. J'assure la relation avec les partenaires, entre autres les Organismes PCID (Partenaire en Communication et Information pour le Développement) et les Stations Radio FM locales affiliées au Projet Radio. Je gère également la relation avec nos groupes cibles (les Groupes d'écoute). Le Projet Radio a débuté en 1999, quant à moi, j'y travaille depuis l'année 2006.

Depuis que vous avez commencé à travailler avec ce projet, quel changement avez-vous pu constater dans votre vie ?

Pour moi personnellement, il s'agit surtout d'un développement de la relation humaine et partenariale. Ce projet m'a permis d'élargir mes relations avec divers organismes et acteurs de développement rural, il en est de même avec les Stations Radio FM locales. En outre, Projet Radio m'a également permis de développer mes capacités et compétences dans le domaine de la communication orale et radiophonique.

Et pour les villages et les alentours du projet, qu'est ce qui a changé à travers ce projet d'après vous ?

Projet Radio a apporté des grands changements dans la vie de la population cible surtout les membres des Groupes d'Écoute. Il s'agit d'un changement positif d'attitude c'est-à-dire que grâce aux émissions radiophoniques d'information et d'éducation élaborées par Projet Radio et ses partenaires, les cibles ont adopté des pratiques et comportements sains en matière de santé de la mère et de l'enfant, en matière de VIH / SIDA et de Planning Familial, dans le domaine environnemental, les questions sociales et administratives ainsi que l'égalité entre les sexes.

En effet, on peut constater dans les villages cibles du Projet une augmentation du taux d'utilisation des services de santé, une amélioration du taux de scolarisation des enfants, surtout les filles, une augmentation du taux de pratique des techniques améliorées si on parle de l'agriculture et enfin une amélioration du taux de possession de la carte des pêcheurs et mareyeurs, une amélioration sur le respect de la saison et zone de pêche ainsi que les législations régissant les pêches maritime et artisanale.

Madame Mamiarisoa Alice RAFANOMEZANA

2) INTERVIEW AVEC JACQUELINE HANTATIANA, RESPONSABLE D'UN GROUP D'ÉCOUTE DU PROJET RADIO

Pouvez-vous vous présenter un peu pour commencer ? Qui êtes-vous, quel rôle tenez-vous exactement dans ce partenariat avec le Projet Radio et depuis quand y avez-vous participé ?

Oui, je me nomme HANTATIANA Jacqueline, je suis membre du Groupe d'Écoute du Projet Radio nommé Fandrosoana (développement), je réside dans le quartier d'Ankilimarovahatse, commune de Betsinjake.

Je suis le premier Responsable de notre Groupe d'Écoute, je m'occupe du maintien et de l'entretien du poste radio à manivelle, en outre, c'est moi qui sensibilise les membres à effectuer une écoute ensemble, je leur communique la date et l'heure de diffusion des émissions. Quelque fois, les membres ne peuvent pas se réunir pour effectuer une écoute

ensemble alors qu'il y a des émissions importantes, je prends note et je partage ces informations au niveau des membres de notre Groupe d'Écoute. Le Groupe d'Écoute a été crée le 19 septembre 2006 et j'assure le rôle de Responsable depuis cet instant.

Depuis que vous avez commencé à travailler avec ce projet, quel changement avez-vous pu constater dans votre vie ?

Premièrement, depuis que nous avons obtenu ce poste radio à manivelle de la part du Projet Radio, mes dépenses pour l'achat des piles a diminué.

En outre, je suis très contente car je peux acquérir beaucoup d'information grâce à ce poste radio à manivelle, j'entends diverses émissions mais également des nouveaux tubes.

Et pour vos voisins, les membres de votre Groupe d'Écoute et leurs environs, avez-vous constaté un changement chez eux depuis que vous avez travaillé avec le Projet Radio ?

Effectivement, j'ai pu constater des changements de comportement au niveau de mes voisins et la population environnante car ce poste radio à manivelle leur permet de recevoir diverses informations et conseils. Je peux citer par exemple l'augmentation de la pratique du planning familial dans cette zone, il en est de même pour le taux de vaccination des enfants de moins de cinq ans. Les couples dans notre village commencent actuellement à savoir les précautions à prendre contre le VIH-SIDA et les adolescents acceptent d'utiliser un préservatif lors des rapports sexuels si ce n'était pas le cas auparavant.

En ce qui concerne l'alimentation des nouveaux nés et des enfants de moins de six mois, les mères de famille ne donne plus de l'eau et de la tisane à leur bébé car elles savent grâce aux émissions radiophoniques que ce n'est pas bien pour leur enfant.

Madame Jacqueline HANTATIANA

3) INTERVIEW AVEC FARALAHY, RESPONSABLE DE LA COMMUNICATION D'UN PCID (PARTENAIRE EN COMMUNICATION ET INFORMATION POUR LE DÉVELOPPEMENT)

Pouvez-vous vous présenter un peu pour commencer ? Qui êtes-vous? Quel rôle tenez-vous exactement dans ce partenariat avec le Projet Radio et depuis quand y avez-vous participé ?

Je me nomme FARALAHY, je suis le Responsable de la Communication de l'ONG ASOS, je m'occupe de la relation partenariale entre ASOS et ALT Projet Radio. Pour cela, j'assure les productions mensuelles des émissions radiophoniques de notre ONG. Je m'occupe de l'identification des besoins en formation de notre personnel en matière de communication.

J'assure également la relation directe avec nos groupes cibles, pour cela, je m'occupe de la création et des suivis des Groupes d'Écoute, de la distribution des postes radio à manivelles octroyés par ALT Projet Radio.

Depuis que vous avez commencé à travailler avec ce projet, quel changement avez-vous pu constater dans votre vie ?

Si je me souviens bien, l'ONG ASOS a commencé à travailler avec le Projet Radio en 2004. Quant à moi, je m'occupais déjà de la communication de notre ONG même si je n'étais que l'Assistant de notre superviseur à ce moment là si on parle de la relation avec Projet Radio. En 2006, ce superviseur a quitté notre ONG et c'est là que j'ai pris en main tout seul la relation avec ce Projet.

Concernant le changement apporté par le Partenariat avec le Projet Radio, l'ONG ASOS a pu élargir ses zones d'action et l'effectif de ses groupes cibles grâces au partenariat avec Projet Radio. Effectivement, ASOS avait comme but de toucher toutes les catégories de personnes par leurs activités or, notre budget est limité et ne nous permet pas d'atteindre ce but. Pourtant, Projet Radio nous a beaucoup aidé à élargir notre zone d'action en travaillant avec plusieurs Stations Radio dans plusieurs zones rurales.

Pour moi personnellement, le changement est énorme, c'est en travaillant avec le Projet Radio que j'ai pu avoir connaissance des méthodes d'identification, d'analyse et d'exploitation des problèmes et lacunes en information au niveau des cibles grâce aux formations reçues par l'équipe de ce Projet. C'est ce projet qui m'a permis de savoir manipuler avec aisance un dictaphone et d'autres matériels utilisés pour les prises de son et la production des émissions radiophoniques.

Projet Radio m'a également permis d'avoir une grande relation avec les Responsables des Stations Radio locales. Je ne parle plus des différentes expériences reçues par les échanges effectués avec les personnels du Projet Radio.

Et pour les villages et les alentours du projet, qu'est ce qui a changé à travers ce projet d'après vous ?

Les émissions de Projet Radio permettent à nos cibles d'effectuer une sorte de visite échange d'idées et d'expériences car même si elles ne se déplacent pas, elles sont au courant de ce qui se passe ailleurs en écoutant seulement les émissions crées par les divers Partenaires du Projet Radio, elles y tirent des enseignements et des conseils.

Les changements apportés par ce projet au niveau des cibles surtout les Groupes d'Écoute sont palpables au niveau

Monsieur FARALAHY

de chaque ménage car si auparavant, le sujet de reboisement était un sujet qui n'intéressait personne, actuellement, le reboisement devient un sujet de conversation et une activité importante pour chaque famille dans nos zones d'actions. Le nombre de pépinières prévu ne suffit plus pour nos cibles actuellement car la demande a augmenté depuis le partenariat avec Projet Radio.

Concernant le domaine de la santé, plus précisément le planning familial, auparavant, le taux de couverture des contraceptifs au niveau de nos cibles n'était que de 11 % alors que depuis que nous avons eu un partenariat avec Projet Radio, le taux a atteint 23 %; Il est à souligner que c'est grâce aux groupes d'écoute mis en place avec Projet Radio (dotation des postes radio à manivelle) que nous avons pu élaborer ces évaluations d'impact de nos émissions.

NOTE DE L'ÉDITION

La radio Freeplay (comme le poste que vous présente Madame Jacqueline HANTATIANA) est une radio à quatre gammes de fréquences (FM - AM - SW1 - SW2) qui a été spécifiquement conçue et élaborée pour être utilisée dans les campagnes en alliant robustesse, autonomie et puissance pour être écoutée par des groupes d'une quarantaine de personnes. Cette radio est unique en étant la première dans son genre à avoir été conçue d'abord à l'intention des femmes et des enfants visés dans les programmes humanitaires.
La radio Freeplay est extrêmement robuste pour pouvoir être utilisée dans des conditions et des climats difficiles en brousse. La radio est facile à utiliser et est puissante en étant également 'écologique' grâce à ses batteries qui se rechargent avec un panneau solaire intégré ou encore la manivelle fixée au dos qui actionne la dynamo. Pour trouver de plus amples renseignements sur la radio Freeplay, vous pouvez vous rendre sur le site de la Fondation Freeplay en suivant le lien http://www.freeplayfoundation.org/

EDITORIAL NOTE

The Freeplay radio (as for example Madame Jacqueline HANTATIANA is holding in her hands) is a four-band (AM / FM / SW1 / SW2) radio designed and developed for specifically rural applications, where this robust and self-sufficient radio can serve groups of up to 40 listeners. This radio is unique in that it is the first radio that has been designed specifically for use by women and children in development initiatives and other humanitarian projects.
The Freeplay radio is engineered to be highly robust for use in rural conditions and harsh climates. It is easy to operate, has a strong reception and is environmentally friendly using either self-charge or solar power. For more information on the Freeplay radio please visit the Freeplay Foundation's website at http://www.freeplayfoundation.org/

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

NA SAROTRA DIA TSY MAINTSY FALY
Monique Rasoanataonadro
(Même si la vie est difficile, il faut savoir être heureux.)
(Even if life is hard we should be happy to live.)

ILAY NALAINA SARY NO NAMPITSIKA AZY
Nadia Manjato
(C'est le fait d'être prise en photo qui l'a fait sourire.)
(She is smiling because a picture is being taken of her.)

RAHOVIANA AHO NO MBA AHAVITA TRANO HO AHY?
Landy Rabemanantsoa
(Quand est-ce que je pourrai construire une maison pour moi ?)
(When will I be able to build my own house?)

MIASA MAFY IZY FA FALY IHANY- ZAZA AMPIASAINA TSY MAHATSIARO MIJALY
Nivo Rakotoarivelo
(Elle travaille dur mais elle est heureuse, c'est une enfant que l'on fait travailler mais elle n'en souffre guère.)
(She is working hard but seems to be happy; she is been forced to work but harldy suffers from it.)

EFA ZATRA NY FIAINANY. VOATERY MIASA NEFA MBOLA ZAZA.
Rakotondrainibe Anja
(C'est sa vie. Elle est obligée de travailler malgré son âge.)
(This is her life. She has to work even though she is still child.)

ZAZA TSY MAHALALA NY LALANA (TSY AZO ATAO NY MAMPIASA ZAZA) FA FALY NY MAHAZO VOLA
Hans Rajaonera
(Elle ignore la loi contre les travaux des enfants mais elle est heureuse à l'idée de gagner de l'argent.)
(She is ignorant of the law which states work for minor is forbidden. However, she seems happy to make some money.)

PLEIN D'ESPOIR, SON MAGNIFIQUE SOURIRE NOUS ENVOIE LE MESSAGE QU'UN JOUR NOUS L'AIDERONS
Ratokinastina Mitsimbina
(Her magnificent smile stems from the hope that one day we will help her.)

FALY LALANDAVA NA SAROTRA AZA NY FIAINANA
(TOETRA ANANAN'NY AKAMAROAN'NY MALAGASY.)

Lalao Andriamahefarivo

(La joie de vivre malgré la dureté de la vie (un caractère que je reconnais chez la plupart des Malgaches.)

(Joy to be alive despite the hardships of life (a character I recognize in most Malagasy.)

ANKIZY MAMPALAHELO IZY SATRIA MIASA FOANA IZY NA DIA TSY TAHA.
OHATRANY EFA ZATRA AMIN' NY FIASANY.

Rakotoarijaona Maeva

(Elle fait pitié car elle travaille même si elle n'en a pas envie. Elle est habituée à sa vie.)

(She is part of the community and helps out even though she might not want to.
She is used to her life.)

ANEFA IZANY FAHANTRANA IZANY DIA TSY MANANKAN' AZY AMPIRATRA TAREHAN' INY.

Ranaivoson Ehret

(Son sourire prouve que sa pauvreté ne l'atteint pas.)

(Her smile shows that poverty is not awaiting.)

AMIN' NY MASONY NO HITAKO FA MISY AFALIANA NO
MANAMPY RAY AMAN' DRENINY AMIN' NY RESAKA VOLA.

Rakoto Raherinjatovo Rijaniaina

(Dans ses yeux il y a le plaisir d'aider ses parents à gagner de l'argent.)

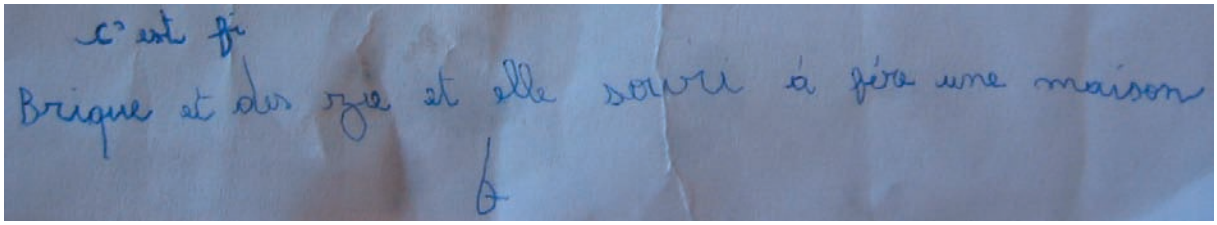
(Her eyes reflect the pleasure of helping her parents earn some money.)

HITA HO TENA FALY IZY NA DIA HITA FA SAROTRA NY MILOLOHA IREO BIRIKY.
TSARA NIFY TOKOA ILAY ZAZAVAVY KELY, TSY HITA SORITRA EO AMINY NY
FAHATRANA. HITA FA MIBANJINA TSARA ILAY MPAKA SARY IZY.

Sylvie Andriambololonera

*(Porter ces briques sur la tête est un dur labeur mais elle est très heureuse. Elle a de si belles dents,
qu'on oublie qu'elle est pauvre. On voit qu'elle pose bien pour la photo.)*

(Carrying bricks is hard labor, but she is very happy. Her teeth are so beautiful that one forgets her poverty.
Obviously she is posing well for the picture.)



Ayoub Camara, 6 ans

(C'est une fille avec des briques et des yeux et elle sourit à faire une maison.)

(She's a girl with bricks and eyes and she is smiling to make a house.)

*MADAGASCAR, UN PAYS DE CONTRASTE OÙ LE BONHEUR
ET LA PAUVRETÉ SE CROISENT SUR LE MÊME VISAGE.*

Yolande Razafindrakoto

(Madagascar, a land of contrast where joy and poverty
are expressed together on the same face.)

Travelling Through Time - Voyage dans le Temps

In this newly introduced rubric the journal would like to invite people to speak about those having left their mark in Conservation & Development in Madagascar. Here we call on Sylvie Domergue to tell us about:

Dans cette nouvelle 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 Sylvie Domergue pour qu'elle nous parle de:

Charles Antoine Domergue, 95 years old
Institut Pasteur de Madagascar, Antananarivo
8 November 2008

Charles Antoine Domergue, 95 ans
Institut Pasteur de Madagascar, Tananarive
Le 8 novembre 2008

CHARLES ANTOINE DOMERGUE

I was very happy when the Journal Madagascar Conservation & Development invited me to write an article about my father, in which I could think freely about his life and accomplishments, without having to emphasize a scientific vision. My father became a legend in his own lifetime, but, at 95, he does not go out anymore, even less so to go on the field explorations that led to his major scientific accomplishments in hydrogeology, ecology and conservation of Malagasy natural landscapes, and even zoology (his work on Madagascar snakes, a result of 30 years of field and academic studies, still remains unpublished for the most part, and I keep in mind the means to make it available to the scientific community as well as to the broader public in the coming years).

Lorsque le Journal Madagascar Conservation & Development m'a demandé de réfléchir à un article dans lequel je parlerais librement de mon père, et ceci dans un premier temps, sans s'attaquer à une vision purement scientifique, j'ai accepté avec reconnaissance car s'il fut autrefois une légende vivante à Madagascar, son grand âge (il a 95 ans) lui interdit aujourd'hui toute sortie et encore moins ces explorations sur le terrain qui l'amenaient alors à des productions scientifiques d'un intérêt majeur, tant dans le domaine de l'hydrogéologie et de la zoologie (son travail sur les serpents de Madagascar, résultat de trente années d'études en pleine nature et en laboratoire, n'est pas encore publié dans son intégralité, et nous envisageons le moyen de le mettre enfin à disposition de la communauté scientifique d'une part, du grand public d'autre part, dans les années à venir), que dans celui de l'écologie et de la préservation de l'espace naturel malgache.

In addition, this hard working field biologist whose passion led him to organize voluntary expeditions during which he collected valuable information that he later shared with the scientific community at the Institut Pasteur de Madagascar, the Muséum national d'Histoire naturelle in Paris and the Faculté des Sciences of Toliara, has never been able to obtain proper business contacts with publishers or trade partners. Moreover, this " savage aristocrat ", as I love to tease him, has tried to escape social life as much as possible and never had the idea to put himself in the public spotlight. He considers that exposing himself in such a way is a kind of flashy boastfulness unworthy of the asceticism and the austerity to which he is attached.

This characteristic made it difficult for his enthusiastic partners to push him to release and share his discoveries, but, fortunately, some part has been published in the bulletins of the Académie Malgache, the Museum, and Institut Pasteur.

In our modern world of incredibly fast means of communication, with technology being more efficient than it has ever been, the deep and also appealing personality of Charles Domergue has spontaneously given rise to a foundation of

D'autre part, cet homme de « brousse » à l'incroyable capacité de travail, que sa passion menait souvent à des missions purement bénévoles au cours desquelles il récoltait les informations précieuses qu'il partageait ensuite avec les scientifiques de l'Institut Pasteur de Madagascar, du Muséum national d'Histoire naturelle de Paris ou la Faculté des Sciences de la ville de Tuléar, a toujours été incapable de mener à bien des relations de type affairiste avec des maisons d'édition ou des partenaires commerciaux. Bien plus, ce « sauvage aristocrate », comme je me plais à l'appeler pour le taquiner, a toujours fui les mondanités et n'eut jamais l'idée de s'exposer à la publicité. Il considère le fait de s'exposer ainsi à l'opinion publique comme une forfanterie tape à l'œil indigne de l'ascétisme et de l'austérité qui lui furent toujours chères.

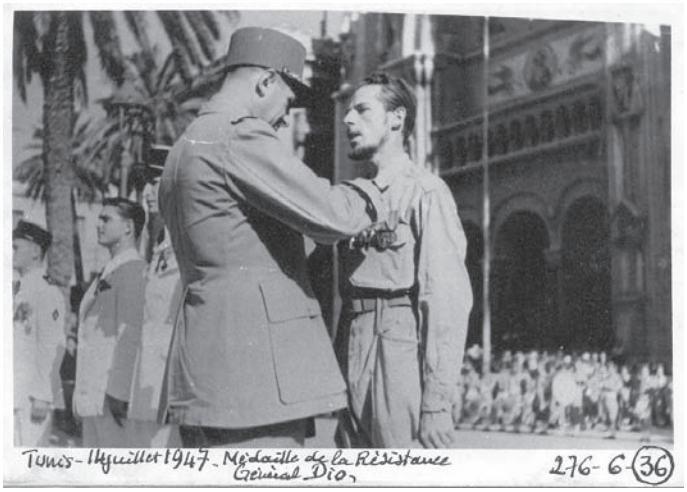
C'est dire la difficulté qui fut toujours celle de son entourage légitimement enthousiaste à le solliciter à porter au grand jour ses travaux dont heureusement une partie fut publiée dans les bulletins de l'Académie Malgache, du Muséum et de l'Institut Pasteur.

Dans ce monde nouveau où la communication et les moyens techniques ont atteint en quelques années des sommets de rapidité et d'efficacité, une 'fondation' des admirateurs de l'œuvre et de la personnalité aussi attachante que « hors

supporters helping to properly release his unpublished data for future generations.
It is up to us now to take over in paying homage to this old school scientist, those of us with knowledge beyond our specialties, to include literature, history and sciences in general.

normes », de Charles Domergue a spontanément émergé avec pour objectif de sauver ses nombreux travaux non publiés pour que la postérité et les générations à venir y aient accès.

Ensemble, il nous appartient dorénavant de prendre la relève pour rendre hommage à ce véritable savant de l'ancienne école, ceux dont les connaissances au-delà de leurs spécialités couvrent des domaines aussi variés que la littérature, l'histoire, les sciences en général.



Charles Domergue's heroic deeds were cited as:

"Remarkable Combatant of the French Forces, for his activity and bravery, arrested by the Gestapo, imprisoned, tortured, did not speak and thus saving his network mates. Deported to Germany, brilliantly escaped"
signed by Charles de Gaulle

Les hauts faits de Charles Domergue lui valurent ces phrases :

« Agent des Forces Françaises Combattantes remarquable par son activité et son courage, arrêté par la Gestapo, emprisonné, torturé, n'a pas parlé, sauvant ainsi les camarades de son Réseau. Déporté vers l'Allemagne, a réussi une brillante évasion »
signées de Charles de Gaulle

For the time being, I will not go into many details of an exceptionally rich biography but could, for instance, cite his academic degrees in Physics, Chemistry and Biology (certificate in 1937), in Botany, Zoology, Geology, general Chemistry (academic certificates obtained between 1938 and 1945), his explorations of pits in Doubs and Jura during pioneering speleological expeditions in the 20s with professor Fournier, or his Bachelor as well as Bachelor of Teaching Sciences, and ending with his last academic degree as a Doctor in Geology for the work accomplished and 1945), his explorations of pits in Doubs and Jura during pioneering speleological expeditions in the 20s with professor Fournier, or his Bachelor as well as Bachelor of Teaching Sciences, and ending with his last academic degree as a Doctor in Geology for the work accomplished both in Tunisia and Madagascar. Charles Domergue has always been able to combine geology and herpetology, and as early as 1946 he published his first book on snakes entitled "Les serpents de Franche-Comté", right after the Second World War and before being decorated with the Resistance Medal for his heroic deeds in the Campaign of France which he rejoined in 1939.

Among his other honorary distinctions, one may cite the Medal of Knight of Nitcham-Iftikar (Tunisia 1950), the Medal of the Legion of Honor, and also the Large Cross of the National Order of Madagascar. Madagascar finally became Charles Domergue's second fatherland, the place where he wants to be buried. But we don't know to which extend his sense of honor and patriotism, influenced by a father committed to France, are his fundamental values, born from self-sacrifice and his friendships with fellow comrades-in-arms, experiences that have marked his life as a man of honor, before he devoted his life to his scientific curiosity and passion.

Sans vouloir entrer pour le moment dans les détails d'une biographie d'une richesse phénoménale, citons pour exemple ses titres universitaires en Physique, Chimie et Biologie (certifié en 1937), en Botanique, Zoologie, Géologie, Chimie générale (certificats d'études supérieures de 1938 à 1945), ses explorations de gouffres dans le Doubs et le Jura lors des expéditions pionnières de spéléologie dans les années 1920 avec le professeur Fournier, sa Licence d'État et Licence d'Enseignement en Sciences, et en 1962 son équivalence du grade de Docteur es Sciences en Géologie, sur la base des travaux effectués en Tunisie et à Madagascar. Charles Domergue a toujours combiné géologie et herpétologie et publiait dès 1946 son ouvrage « Les serpents de Franche-Comté » juste après la seconde grande guerre et avant d'être décoré de la Médaille de la Résistance pour ses hauts faits lors de son engagement dans la Campagne de France qu'il rallia en 1939.

Parmi ses autres distinctions honorifiques, on peut aussi trouver la Médaille d'Officier du Nitcham-Iftikar (Tunisie 1950), d'Officier de la Légion d'Honneur et enfin la Grand Croix de l'Ordre National Malgache. Car Madagascar est bien devenue la seconde patrie de Charles Domergue, celle où il veut être enterré mais on ne sait pas assez à quel point son sens de l'honneur, son patriotisme influencé par l'exemple de son père au service de la France sont ses valeurs fondamentales nées des sacrifices qu'il s'est imposés et des amitiés contractées avec ses compagnons d'arme qui furent les expériences les plus marquantes de sa vie d'homme d'honneur et d'homme de cheval, avant qu'il ne consacre sa vie à sa passion et sa curiosité scientifique.

Rose Lavite, his partner in life during 30 years and who assisted him in his research on snakes and birds of Madagascar with a never-failing devotion, sharing the nights in tents or in the car, in the middle of nowhere, laying out his work for publications for the Muséum national d'Histoire naturelle in Paris, under the direction of Doctor Brygoo, then Director of Institut Pasteur of Madagascar.

Rose Lavite, sa compagne pendant 30 ans et qui le seconda dans ses recherches sur les serpents et les oiseaux de Madagascar avec un dévouement à toute épreuve, partageant les nuits sous la tente ou dans la voiture, en brousse, mettant en page ses travaux pour des publications du Muséum national d'Histoire Naturelle de Paris, sous la direction du Docteur Brygoo, alors Directeur de l'Institut Pasteur de Madagascar.

1972. Dead snake collected on a southern road; held by Sylvie Domergue.

1972. Serpent mort ramassé sur les routes du Sud tenu par Sylvie Domergue

1978. Lake Ihotry. My father's favorite place. As we were used to, we spent the night sleeping in our car on the banks of brackish Lake Ihotry, beloved by migrant flamingoes and surrounded by hundred-year-old baobabs. It was a place fairly difficult to reach but here wildlife exulted far from any trace of civilization. These young people spent the night looking after our campsite until we woke up, to welcome us and also to protect us from bad "night spirits."

1978 Lac Ihotry. Le coin préféré de papa, nous avions comme à l'accoutumée passé la nuit dans la 4L, sur les rives du lac à l'eau saumâtre qu'affectionnent les flamants roses en migration et bordé de baobabs centenaires. Un endroit qui était difficile d'accès et où la nature exultait loin de toute trace de civilisation. Ces jeunes gens étaient venus monter la garde auprès de notre campement jusqu'à notre réveil, pour nous souhaiter la bienvenue et nous protéger d'éventuels « mauvais esprits » nocturnes.

Plateau de l'Horombe, 28 July 1978, 08h45, 18 km from the junction to road to Betroka, i.e. 644 km south of Antananarivo (this kind of detail is found all over my father's work; his collections and notes are therefore only more invaluable in modern studies.) After a chilly night spent in the famous Renault 4, I posed in front of a beautiful specimen of *Aloe macroclada*. The Renault 4 made it through the entire countryside and even if my father regularly received amazing offers of purchase, he always declined them with modesty.

Plateau de l'Horombe le 28 juillet 1978 à 8h45, à 18 km de la bifurcation du PK 626, soit PK 644 route de Betroka' (ce type de précision est rencontré dans tous ses travaux, et ses collections et notes n'en sont que plus précieuses dans les études actuelles). Après une fraîche nuit dans la célèbre 4L, il me faut poser devant un beau spécimen d'Aloe macroclada. La 4L sillonna tout le pays pendant trente ans et si mon père recevait régulièrement des offres d'achat d'un montant faramineux, il les déclinait toujours avec modestie.

One day I crashed the back wing of the Renault 4 against a pine at the Marine Station of Toliara, city where my father, Charles Domergue, taught ecology, comparative anatomy, zoology and hydrogeology. From this place, students from the University regularly joined him on trips to superb spiny forests located about 30 kilometers to the north (Ifaty, known as PK 32 reserve or „Domergue Forest") and were so enthusiastic and eager to take part in the conservation of their natural heritage. I will not forget the session of reprimands after this incident! But without any terror, because Charles Domergue has always been a man for whom uncontrolled anger was unworthy of the education he had received: a properly educated person keeps their cool and considers their remarks under any circumstances, and remains polite and obliging even in facing a lout; in my opinion, this distinction and this elegance, with an honesty never taken at fault, his sense of honour which has always been essential to him, one of Charles Domergue's trademarks.

Un jour j'emboutis l'aile arrière de la 4L contre un pin de la Station Marine de Tuléar, ville où mon père Charles Domergue enseignait l'écologie, l'anatomie comparée, la zoologie et l'hydrogéologie. C'est de cet endroit qu'il emmenait régulièrement dans les belles forêts épineuses situées à une trentaine de kilomètres au nord (Ifaty, réserve du « PK 32 » portant le nom de « Forêt Domergue ») des étudiants de l'Université enthousiastes et désireux de participer à la conservation de leur patrimoine naturel. Je n'oublierai pas la séance de réprimandes après cet incident ! Cela sans terreur aucune d'ailleurs, car Charles Domergue a toujours été un homme pour qui les emportements incontrôlés étaient indignes de l'éducation qu'il avait reçue : un homme ou une femme correctement éduqué(e), devait en toute circonstance garder son sang-froid et mesurer ses propos, rester poli(e) et complaisant même en face d'un rustre ; cette distinction et cette élégance sont à mon avis, avec une honnêteté et une loyauté jamais prises en défaut, ce 'sens de l'honneur' qui lui a toujours été essentiel, l'une des 'marques de fabrication' de Charles Domergue.

Charles Domergue recounts his life without ever losing his train of thought, while traveling from the Jura to Tunisia, always coming back to Madagascar where he cast anchor and where he gave the best part of his life. In the deep South, in the driest places of Androy, Mahafaly plateau or north of Toliara, in regions where even the largest rivers hardly run more than a few days a year at best, the hydro-geologist worked with people of the country

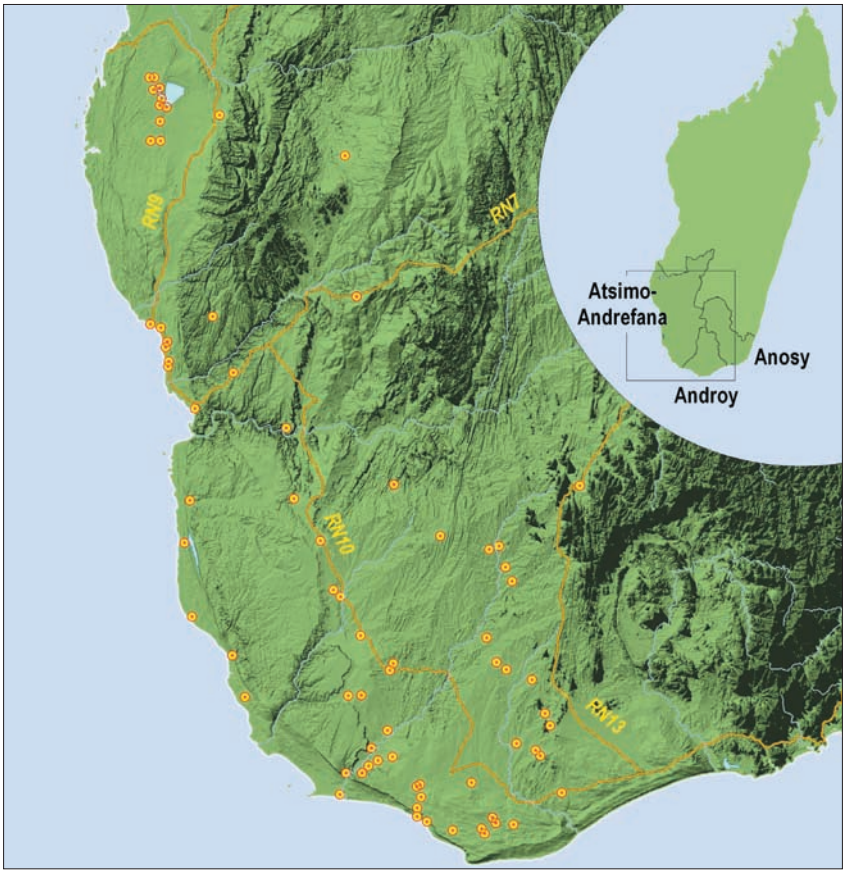
Charles Domergue conte sa vie sans jamais perdre le fil de ses pensées, en voyageant du Jura à la Tunisie pour revenir inlassablement vers Madagascar. Car c'est à Madagascar que Charles Domergue s'ancrera et qu'il donnera le meilleur de sa vie. Dans le grand Sud, dans les endroits les plus arides de l'Androy, du plateau Mahafaly et au nord de Tuléar, dans ces contrées où même les plus grands fleuves ne coulent guère que quelques jours au

Charles Domergue's 'trademarks'

When he had to attend official 'receptions' (he detested them by principle ...) and when he was in the field, Charles Domergue always wore impeccable trousers, shirt (sometimes a tie) and jacket, but in the field he also had a kaki cap and these classic shoes which nowadays teenagers are so enthusiastic about: the Converse (known as Chucks in historical time); nothing would have taken away from his distinguished elegance of a cavalier and the spiritual and inspired level-headedness where his sense of diplomacy was only equaled by the incredible richness of his remarks. These qualities were much appreciated in all social circles, from downtown where ladies fought over the honor to be greeted by cordial 'My respects, Madam ...' but also in the villages where he knew all chiefs, priests, and the children whom he watched grow up and who rushed to join him in places where they could show him some birds, some snakes or a source of water that he could study for a possible pump or drilling project.

'Marques de fabrication' de Charles Domergue

Dans les 'réceptions' où il a parfois été obligé de se rendre (et que par principe il abhorrait ...) comme en pleine brousse, Charles Domergue conservait pantalon, chemise (parfois cravate) et veste impeccables mais en brousse il s'autorisait le port de la casquette kaki et ce qui fait aujourd'hui la folie des jeunes : son inséparable paire de « converses » (on appelait ça des « tennis », avant...) ; rien ne l'aurait éloigné de cette élégance distinguée de cavalier et de cette pondération toujours spirituelle et indéfectiblement inspirée, où le sens de la diplomatie le disputait à l'incroyable richesse des propos. Ces qualités furent appréciées dans tous les milieux, en ville les dames se disputaient l'honneur d'être saluées par de chaleureux 'Mes hommages, madame ...' et en brousse où il connaissait tous les chefs de village, les curés, les enfants qu'il voyait grandir et qui se bousculaient pour l'accueillir à chacun de ses passages, et l'accompagner dans les lieux où ils savaient pouvoir lui montrer tel oiseau, ou tel serpent, ou encore telle source qu'il pourrait étudier dans la perspective éventuelle d'un projet de pompe ou de forage.



Study localities for the birds of the Collection Domergue & Lavite housed at the Muséum national d'Histoire naturelle in Paris.

Les stations d'études des oiseaux de la collection Domergue & Lavite déposée au Muséum national d'Histoire naturelle de Paris.

to dig wells to provide clean and fresh water to villages where so many people had to survive with brackish water or had to walk hours to seek this rare commodity. From the region of Sainte Marie Cape to Lake Ihotry, he explored the region's hydrology and geology, and also its natural history.I cannot summarize the work achieved and the personality of Charles Antoine Domergue in an anecdotal way or through the description of his accomplishments. I have rummaged in his memory boxes and dislodged some photographs that I am happy to share with you but they are so little and give such an incomplete portrait of this exceptional man, of who he was and still is at 95 years; I am henceforth committed to the publication of his work, stage by stage, articles and books relating to his studies, with the aim of paying homage to the astonishing work of a life primarily devoted to understanding nature, work which helped solve many questions regarding water supply in deserts and arid regions, and with an ultimate aim of offering pathways to understanding extremely topical ecological problems.

I would like to thank all the friends, fellow travelers met on roads and sandy tracks for their impassioned interest towards my father, for their will to bring his work to light, and I am glad to have been called upon to speak freely and modestly about my favorite hero... and I hope that these pages will have stimulated the interest and the sympathy of its readers.

SYLVIE DOMERGUE

mieux par an, l'Hydrogéologue a œuvré avec les gens du pays pour creuser des puits et fournir eau claire et douce aux villages où tant de gens se contentaient souvent d'eau saumâtre ou devait aller tellement loin pour chercher cette denrée rare. De la région du cap Sainte-Marie jusqu'au lac Ihotry, les explorations furent ainsi hydrologiques et géologiques, mais aussi naturalistes.

Il m'est impossible de résumer, de manière anecdotique ou à travers la description de ses travaux, l'œuvre et la personnalité de Charles Antoine Domergue. J'ai creusé dans ses boîtes à souvenir, j'y ai délogé quelques photos que je vous livre mais il s'agit d'un portrait bien incomplet de cet homme exceptionnel qu'il fut et est encore à 95 ans ; je suis dorénavant engagée dans la publication de son œuvre, étape par étape, avec des articles et des ouvrages le concernant, dans le but de rendre hommage à l'œuvre phénoménale d'une vie essentiellement consacrée à la compréhension de la Nature qui permit de résoudre d'innombrables problèmes concernant l'alimentation en eau des contrées désertiques ou semi désertiques, et dont le but ultime est de proposer des pistes pour la résolution de problèmes écologiques d'une actualité brûlante.

Je remercie tous les amis, compagnons de route et de pistes ensablées pour l'intérêt passionné qu'ils portent à mon père, pour leur volonté de mettre au grand jour ses travaux, pour cette libre parole qui m'a permis bien modestement de vous parler de mon héros préféré ... et j'espère que cet article aura stimulé l'intérêt et la sympathie de son lectorat.

ANNOUNCEMENT: NEW JOURNAL FOR MADAGASCAR

MALAGASY NATURE

Malagasy Nature est une revue internationale sur l'histoire naturelle de Madagascar et des îles voisines produite par l'Association Vahatra. La revue est enregistrée sous l'ISSN 1998-7919.

OBJECTIFS

- *Aider les scientifiques nationaux, surtout les jeunes chercheurs, à faire connaître le fruit de leur travail afin d'avancer sur les plans académique et professionnel ;*
- *Constituer une plate forme d'échange et de partage d'informations ;*
- *Véhiculer des informations utiles dans le domaine de la science et de la conservation de la biodiversité ;*
- *Donner la chance et surtout aux Malgaches de faire connaître les richesses naturelles de Madagascar.*

ÉDITRICE EN CHEF

Marie Jeanne Raherilalao

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Steven M. Goodman, Achille P. Raselimanana, Malalarisoa Razafimpahanana, Voahangy Soarimalala et Lucienne Wilmé.

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FRÉQUENCE DE PARUTION

Revue annuelle publiant des articles en français et en anglais.

FINANCEMENT

John D. and Catherine T. MacArthur Foundation pendant les trois premières années.

DIFFUSION

Gratuite pendant les deux premières années. Toutefois, après cette période, un abonnement est envisagé.

ADRESSE

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Malagasy Nature is an international journal concerning the natural history of Madagascar and neighboring islands published by the Association Vahatra. The journal is registered with ISSN 1998-7919.

OBJECTIVES

- To support national Malagasy scientists, particularly young researchers, to publish the results of their scientific work and advance in the context of their academic and professional careers;
- Act as a forum for scientific exchange of information;
- Convey useful information in the domain of science and conservation biology;
- To provide opportunities, particularly for the Malagasy, to learn about their natural patrimony.

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PUBLICATION FREQUENCY

One volume per year will be published with articles in either French or English.

FUNDING

John D. and Catherine T. MacArthur Foundation is providing funding during the first three years.

DISSEMINATION

Distributed for free during the first three years; thereafter, through paid subscriptions.

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IMPRESSUM

Madagascar Conservation and Development is the journal of Madagascar Wildlife Conservation (MWC) and the Jane Goodall Institute (JGI Switzerland). It is owned by these two institutions and is produced in these institutions own responsibility.

COVER PICTURE: Carrying the Earth of Madagascar by Peter Oxford

EDITORIAL DRAWING: Pascal Girod [Madagascar Wildlife Conservation Switzerland]

DESIGN: Thomas Lehner [Hochschule für Gestaltung und Kunst Basel]

LAYOUT: Stephanie Züllig [Madagascar Wildlife Conservation Switzerland]

FUNDRAISING: Julian Cooke [Anglo-Malagasy Society, UK]

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BIC (Bank Identifier Code): POFICHBEXXX
Adress: Swiss Post – PostFinance
Nordring 8
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ISSN 1662-2510